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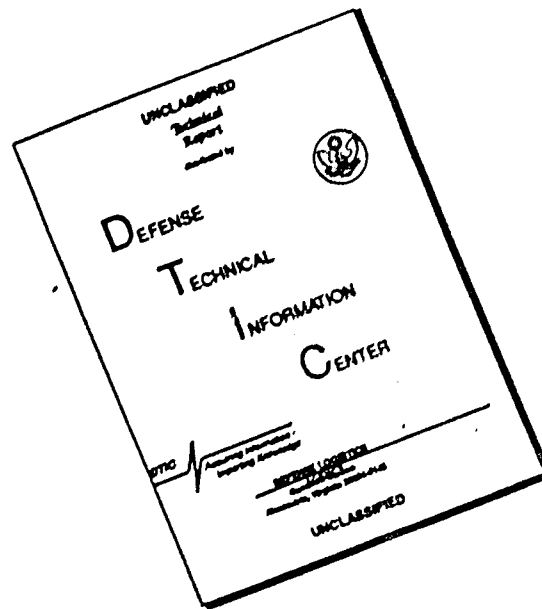
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REPORT OF PROJECT NR AVN 2656
EFFECT OF WING-TIP VORTICES AND SONIC SHOCK
ON ARMY AIRCRAFT IN FLIGHT

May 1957

Robert L. Head

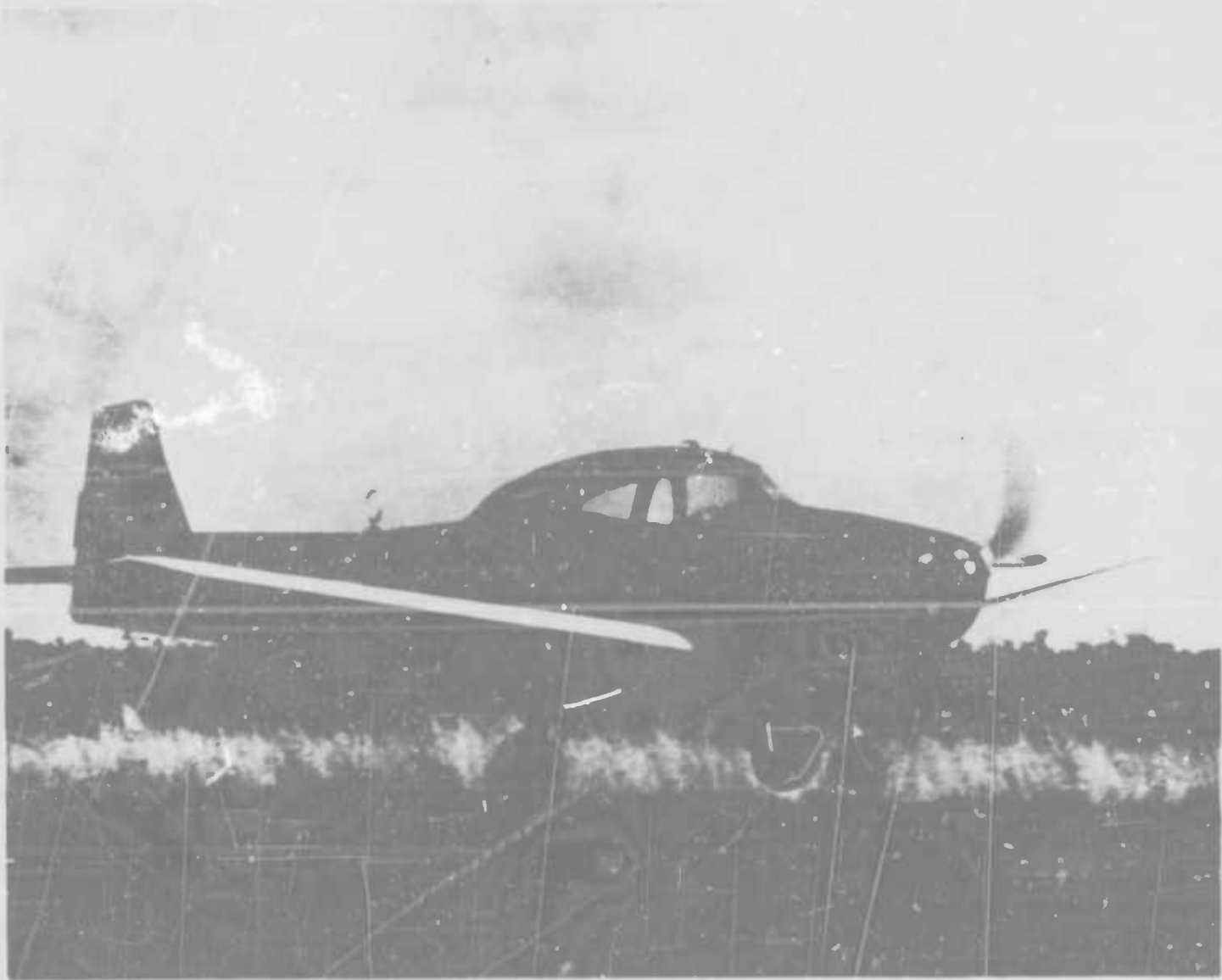
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UNITED STATES ARMY AVIATION BOARD
Fort Rucker, Alabama

REPORT OF PROJECT NR AVN 2656

EFFECT OF WING-TIP VORTICES AND SONIC SHOCK ON ARMY AIRCRAFT IN FLIGHT

Abstract of Report

1. PURPOSE.

- a. To determine the duration, characteristics and intensity of wing-tip vortices produced by specific highly wing-loaded aircraft.
- b. To determine the effect of wing-tip vortices on Army aircraft.
- c. To determine the effect of sonic shock of fixed-wing aircraft in flight.

2. SCOPE. Tests were conducted at Range 52, Eglin Air Force Base, Florida, during the period 31 October - 19 December 1956. Six flight hours of preliminary testing were conducted to determine the duration and characteristics of wing-tip vortices produced by F-100C aircraft flown at various configurations and airspeeds under various atmospheric conditions. Ten flight hours of test were conducted in which a QL-17 was used to intercept the wing-tip vortices created by F-100 and B-47 aircraft. Two flight hours of testing were conducted in which a piloted L-19 intercepted wing-tip vortices created by an F-100. Three flight hours of tests were conducted in which a QL-17 in flight was subjected to sonic shock created by an F-100.

3. SUMMARY.

a. The duration of wing-tip vortices is governed primarily by the turbulence structure of the atmosphere in which generated. Greater vortex disturbances are generated when the generating aircraft are flown at low airspeeds. Any turbulence or wind has an immediate dispersing effect on the duration of wing-tip vortices.

b. Up to time intervals of 30 seconds behind an F-100 flown in landing configuration at airspeeds of 200 knots, the vortex effect may be of such magnitude that a light airplane intercepting the disturbances could not be held in straight and level flight. If the light aircraft were at low speeds, such as approach or landing, it could become uncontrollable to such an extent that a crash could not be avoided. It is highly improbable that an airplane would remain in vortex turbulence long enough to make a complete roll. The most likely response would be to roll to an inverted position and be thrown out of the vortex.

c. No structural damage was sustained by the test aircraft penetrating the wing-tip vortices created by F-100 and B-47 aircraft during this test. However, based on negative loads recorded during this test, it appears possible that, under conditions of extremely stable air, light airplanes penetrating the wing-tip vortices generated by highly wing-loaded aircraft flown at low airspeeds could sustain structural damage, particularly if the lightly wing-loaded airplane was being operated at higher than normal cruise speed.

d. Sonic shock waves generated at airspeeds up to Mach 1.05 and separations as near as 200 feet did not cause any structural damage to the QL-17. There were no visual indications that the flight path of the QL-17 was in any way affected by sonic shock waves. However, it cannot be deduced from this test that light aircraft would not sustain structural damage from sonic shock waves generated by airplanes flown at speeds well above Mach 1.

e. The results of this test indicate a definite need for additional information on the effect of vortex disturbances and sonic shock on light aircraft. A comprehensive study of these problems, involving theoretical studies, engineering tests and flight tests, will be required to secure any significant information. Such studies are beyond the capability of this Board.

4. DISCUSSION.

a. Air Research and Development Command, United States Air Force, Wright-Patterson AFB, Ohio, is initiating a program to determine the effect of turbulence on aircraft landing every 30 seconds. This program will include both theoretical studies and flight tests to determine the effect of turbulence on aircraft in flight. Flight tests will include a study of the effect of turbulence generated by fighter, bomber, and transport airplanes on different types of aircraft in traffic patterns and during landings and takeoffs.

b. Air Research and Development Command, Wright-Patterson AFB, Ohio, is conducting an investigation of the sonic shock problem. This investigation will include a comprehensive theoretical study of sonic shock phenomena and effects. It will also include flight tests and studies of sonic shock waves generated by aircraft capable of Mach speeds much higher than those attained during the tests conducted by this Board.

5. CONCLUSIONS.

a. In regard to the duration, characteristics and intensity of wing-tip vortices:

(1) The duration is governed primarily by the atmospheric conditions existing. Any air disturbance has an immediate dispersing effect.

(2) The greatest disturbances produced by any aircraft occur when that aircraft is traveling at low airspeeds, such as in landing and takeoff patterns.

(3) No quantitative conclusions could be reached on intensity; however, the vortex effect can be of such intensity that a serious control

problem will be created when light airplanes encounter the disturbances at low airspeeds.

b. Wing-tip vortices can produce momentary loss of control to Army airplanes and could under certain conditions produce structural damage to light airplanes.

c. Further tests and studies, by agencies capable of more comprehensive investigations than this Board, should be made of the effects of sonic shock and wing-tip vortices on Army aircraft.

6. RECOMMENDATIONS. It is recommended that:

a. The US Army monitor the study and flight-test program being initiated by Wright Air Development Center, Air Research and Development Command, USAF, to study the effect of turbulence on aircraft landing every 30 seconds.

b. The US Army monitor the sonic boom program being initiated by Wright Air Development Center, Air Research and Development Command, USAF.

c. The US Army support further investigation of the sonic shock and wing-tip vortices problems to the extent necessary to determine effects on Army aircraft.

FINAL REPORT OF PROJECT NR AVN 2656

EFFECT OF WING-TIP VORTICES AND SONIC SHOCK ON ARMY AIRCRAFT IN FLIGHT

Copies of this report can be obtained

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Table of Contents

	<u>Page</u>
I. AUTHORITY.	1
II. PURPOSE.	1
III. SCOPE.	1
IV. GENERAL INFORMATION	
1. Background	1
2. Description of Materiel.	3
3. Problems Encountered	7
V. TESTS	
1. General.	7
2. Preliminary Test	9
3. Vortex Penetrations	
a. Drone Penetrations	9
b. Piloted Penetrations	13
4. Sonic Shock.	14
VI. DISCUSSION	14
VII. SUMMARY.	15
VIII. CONCLUSIONS.	16
IX. RECOMMENDATIONS.	16
X. REFERENCES	17
XI. COORDINATION	18

Appendices

Appendix A	A-1
Appendix B	A-15

REPORT OF PROJECT NR AVN 2656

EFFECT OF WING-TIP VORTICES AND SONIC SHOCK ON ARMY AIRCRAFT IN FLIGHT

List of Figures

<u>Figure</u>		<u>Page</u>
1	F-100, Front View.	2
2	Smoke Grenades Positioned in 500-Pound Bomb Case	3
3	B-47 Airplane.	4
4	Drone-Control Equipment Mounted in L-23 Airplane	4
5	Airplane-Control Box Mounted in L-23	5
6	Drone Ground-Control Station	5
7	Ground-Control Station Airplane-Control Box.	6
8	Test Site.	8
9	Ground-Control Site, Aerial View	8
10	B-47 Passing Under QL-17	10
11	Test Data.	11
12	Test Data.	12
13	F-100 Passing Under L-19	13

UNITED STATES ARMY AVIATION BOARD
Fort Rucker, Alabama

REPORT OF PROJECT NR AVN 2656

EFFECT OF WING TIP VORTICES AND SONIC SHOCK ON ARMY AIRCRAFT IN FLIGHT

I. AUTHORITY. Letter, ATBG-DG 452.1, Headquarters Board Nr 6, CONARC, 22 March 1956, subject: "Effect of High Speed Vortices and Sonic Waves on Aircraft," and indorsements thereto.

II. PURPOSE.

1. To determine the duration, characteristics and intensity of wing tip vortices produced by specific highly wing-loaded aircraft.
2. To determine the effect of wing-tip vortices on Army aircraft.
3. To determine the effect of sonic shock on fixed-wing Army aircraft in flight.

III. SCOPE. Tests were conducted at Range 52, Eglin Air Force Base, Florida, during the period 31 October - 19 December 1956. Six flight hours of preliminary testing were conducted to determine the duration and characteristics of wing-tip vortices produced by F-100C aircraft flown at various configurations and airspeeds under various atmospheric conditions. Ten flight hours of test were conducted in which a QL-17 was used to intercept the wing-tip vortices created by F-100 and B-47 aircraft. Two flight hours of testing were conducted in which a piloted L-19 intercepted wing-tip vortices created by an F-100. Three flight hours of tests were conducted in which a QL-17 in flight was subjected to sonic shock created by an F-100.

IV. GENERAL INFORMATION.

1. Background.

a. There has been considerable speculation as to the effect of sonic shock and wing-tip vortices on lightly wing-loaded aircraft. Numerous studies in these areas have been made by federal agencies as well as private organizations. Many questions, however, involving operational problems of Army aircraft remained unanswered.

b. In February 1956 a crash of a U-1A "Otter" airplane, apparently caused by penetrating the wing-tip vortices of a CF-100 airplane, emphasized the need for a more thorough and complete investigation. Although a later, second "Otter" accident of a similar nature was attributed to malfunction of the flap valve, the problem of possible damage from wing-

tip vortices still remained. This Board recommended that tests be conducted to obtain operational information on the potential hazard of these vortices and also to investigate the possibility of damage from sonic shock. In April 1956, Project Nr AVN 1956, "Effect of Sonic Shock on Ground Dispersed Army Aircraft and Related Equipment," was completed and the results submitted as a separate report.

c. In order to make a "safe side" approach to tests involving airborne Army aircraft, recommendations were made and approved for use of a QL-17 drone aircraft in conducting tests. Two such aircraft were obtained from the Signal Corps and a contract for modification by TEMCO Aircraft Corporation was initiated. This contract included modification of a Board L-23 for use as a drone mother ship and logistical support of drones and drone control equipment during tests.

d. Various manufacturers and interested agencies were contacted by this Board in regard to their experience and interest in this field. Among agencies showing interest was Beech Aircraft Corporation. This company offered to provide engineering support and analysis of the Board's test, under direction of Board personnel, at no expense to the government. This offer was accepted and, as a result, a minimum of two Beech engineers were present during all physical testing. Extracts from the Beech report are included as Appendix A.

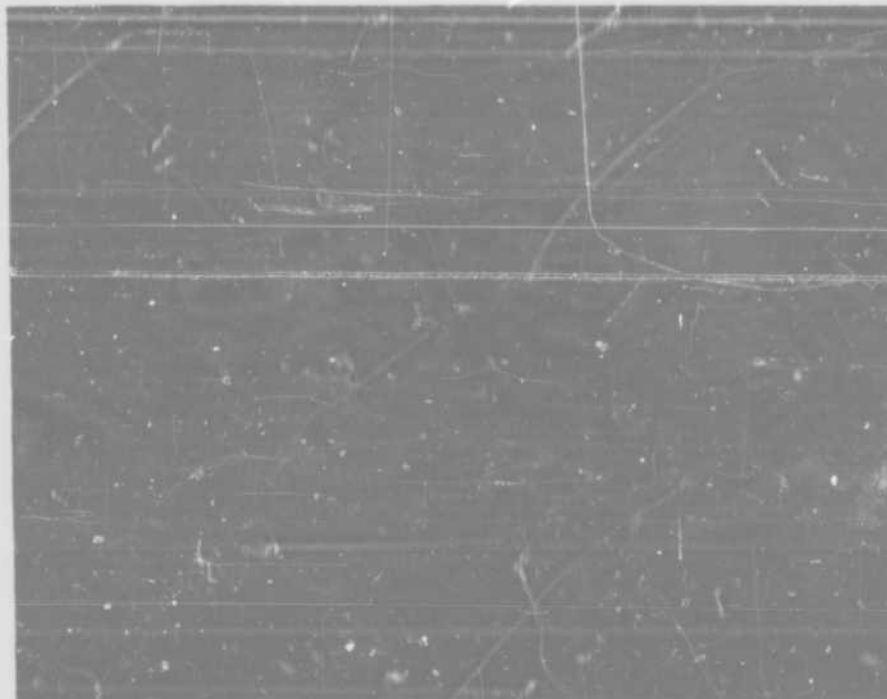


Figure 1. F-100, Front View

2. Description of Materiel.

a. USAF Equipment.

(1) An F-100C aircraft was equipped with six pylons on which 500-pound bomb cases were mounted. Eighteen two-minute smoke grenades, used to generate smoke to mark the vortices of the aircraft in flight, were positioned inside each bomb case and wired to the chemical circuit of the aircraft.



Figure 2. Smoke Grenades Positioned
In 500-Pound Bomb Case

These smoke bombs could be triggered individually to mark the vortex pattern. A maximum of six markings by smoke were possible per sortie. The F-100 was also loaded with 800 rounds of 20-mm. ammunition which was to be used to destroy the drone if destruction became necessary and command destruction could not be effected.

(2) A B-47 was loaded with eighteen two-minute smoke grenades in the JATO rack to dispense a smoke trail to mark wing-tip vortices of the bomber on one pass per sortie.

Figure 3.

B-47 Airplane



b. US Army Equipment.

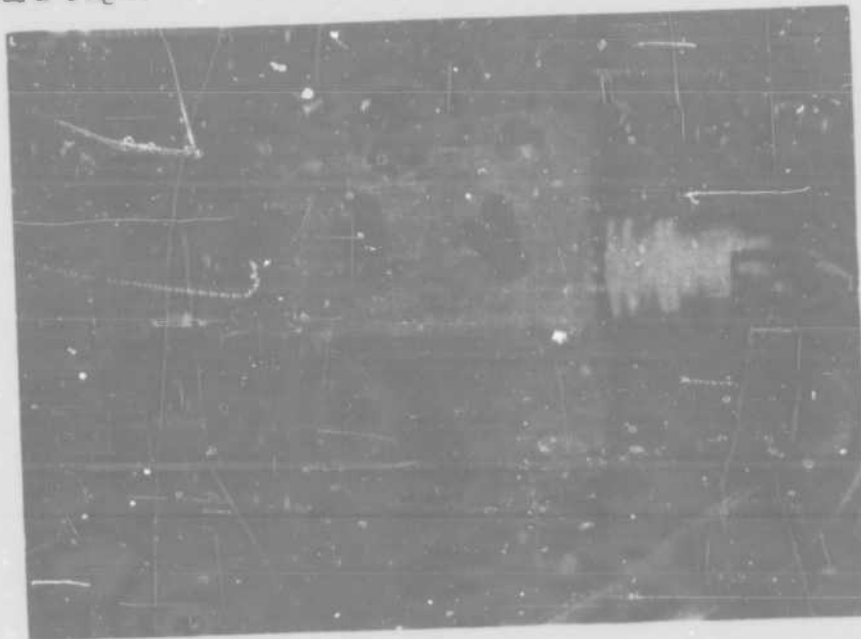
(1) An L-23 was modified for use as a mother ship for remote control of QL-17 drone aircraft. Remote-control equipment was removed from a ground-control station and installed in the baggage compartment of the L-23.



Figure 4. Drone-Control Equipment Mounted
In L-23 Airplane

An airplane-control box was installed in the cockpit of the L-23 to allow operation from the forward right hand seat. The airplane-control box was

Figure 5.
Airplane
Control
Box Mounted
In L-23



modified for remote-control operation of destruction and recorder systems installed in the drone aircraft.

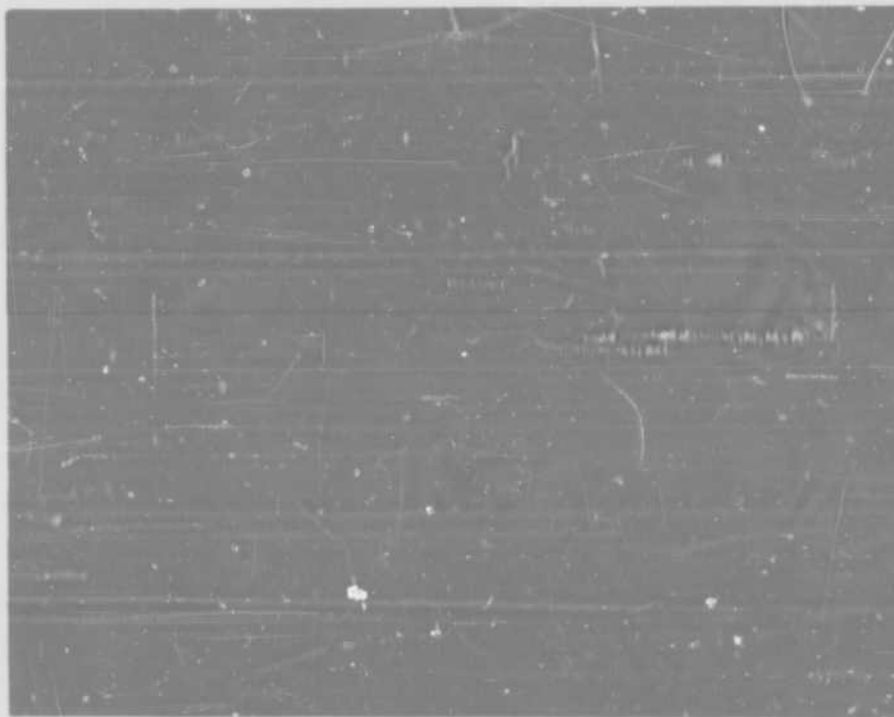
(2) The ground-control station consisted of an antenna mast assembly, a heavy-duty sheet-metal box containing VHF communication



Figure 6. Drone Ground-
Control Station

equipment and a remote-control radio for the purpose of remotely controlling drone aircraft. The ground-control station and airplane-control box

Figure 7.
Ground-Control
Station Airplane-
Control Box



were modified to permit remote-control operation of destruction and recorder systems installed in the drones.

(3) Two QL-17's were modified for installation of instrumentation and destruction systems. Instrumentation provided for recording the following data:

- (a) Vertical acceleration
- (b) Lateral acceleration
- (c) Longitudinal acceleration
- (d) Airspeed change
- (e) Altitude change
- (f) Roll attitude
- (g) Pitch attitude
- (h) Yaw attitude

To reduce congestion caused by recording eight signals on oscillograph tape, lateral and longitudinal acceleration signals were not recorded.

Acceleration signals from accelerometers were fed through a bridge balance unit to an oscillograph. All other signals were picked up in the autopilot system and fed through a demodulator to the oscillograph recorder. The QL-17 was equipped with a command destruction system which permitted the elevator to be positioned to a hard "down" position on command from the operator. This system consisted of an electrical lock-in relay, associated wiring, one channel of the radio link, and a destruction switch on the airplane-control box of the ground station and the mother ship.

3. Problems Encountered.

a. Visualizing the Vortex Wake. The F-100 emitted smoke at a constant mass rate which could not be varied. Thus, moving at an airspeed of 200 knots it traveled a distance of approximately seven and one-half miles while emitting smoke; at an airspeed of 400 knots, the same volume of smoke was dispensed over a distance of approximately 15 miles. At low speeds, the vortex pattern could be marked to some degree up to time intervals of 30 seconds; on high speed runs, 5 to 10 seconds was usually the maximum time the smoke was persistent enough to be used as a reference. Due to the limited volume of smoke available to mark the vortex pattern, photographic recordings attempting to show the characteristics, duration, and intensity of vortex actions were of limited value.

b. Drone Penetration. Directing drones by remote control into even a well-defined smoke trail was exceedingly difficult. Judging the position of the drone in relation to the smoke path was hampered by the lack of references available to aid the drone-control pilot's depth perception. Efforts were made to aid depth perception by laying two smoke trails; however, the smoke trails were too close together to prove effective. Drone operations were difficult with cross winds of more than 5 knots. Vertical turbulence caused the drone to fight to hold altitude, and abrupt changes of 50 feet were not uncommon.

c. Weather. Operations were conducted in the early morning to minimize the effect of turbulence and winds on vortex patterns. Fog and low ceilings often delayed scheduled takeoffs until VFR operations could be conducted. Late morning and afternoon operations were often cancelled due to winds and turbulence.

V. TESTS.

1. General. Tests were conducted at Eglin AFB, Range 52, which incorporates a 5500-foot runway. It is located 17 miles northeast of Eglin Main. The north end of the runway was used as the focal point of the test and intercepts were at an altitude of approximately 1,000 feet above that point. A ground-control station, communications station, motion picture cameras, and observers were positioned approximately 4,000

feet south of the intercept point. A second station with observers, camera crews, and a communications vehicle was established approximately 300 feet to the right of the intercept point. Aerial observation and motion pictures were taken from a helicopter which flew near the intercept point.

Figure 8.
Test Site

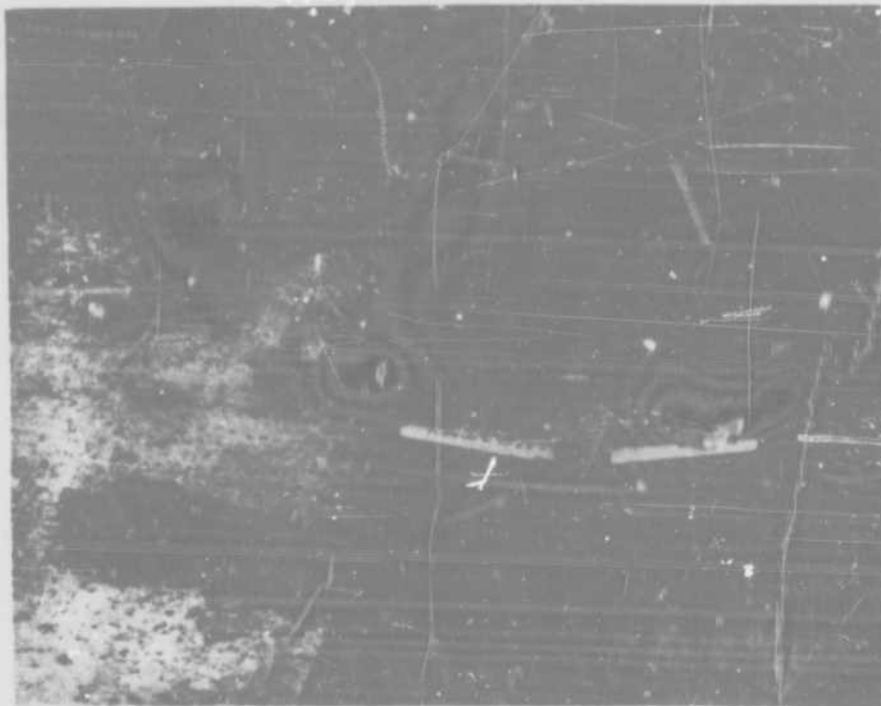
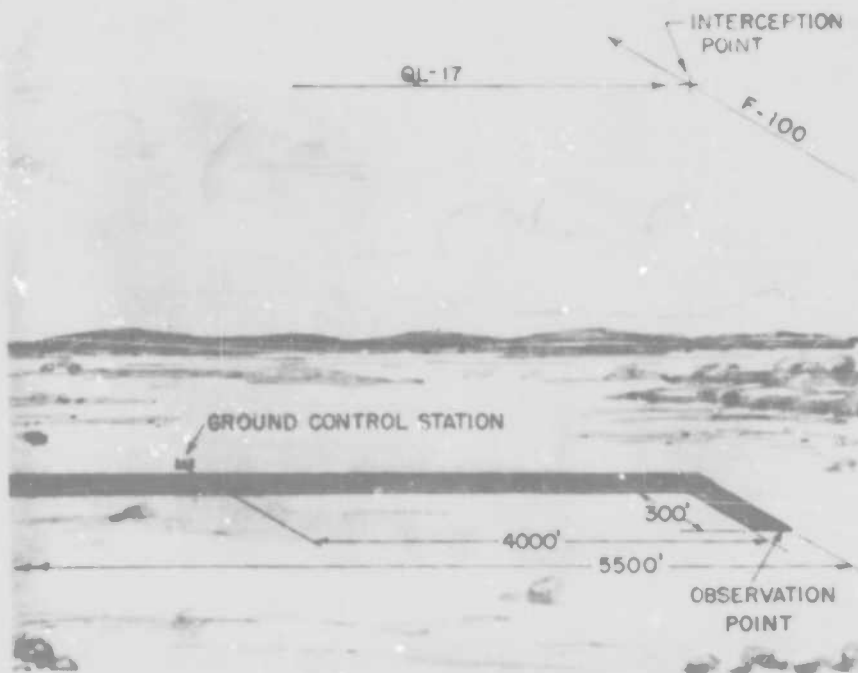


Figure 9.
Ground-Control
Site, Aerial
View

2. Preliminary Tests.

a. Six hours of preliminary tests were conducted to determine the duration and characteristics of wing tip vortices produced by an F-100C being flown at various configurations and airspeeds. The F-100, equipped with smoke bombs, was flown over the intercept point in the following configurations and airspeeds.

- (1) High speed, 400 knots, clean.
- (2) Low speed, 200 knots, clean.
- (3) Low speed, 200 knots, landing configuration.

Twelve runs were made and the vortices, marked by smoke dispensed from the F-100, were studied by observers and photographed with motion picture cameras. Runs were made under atmospheric conditions in which little or no turbulence and wind existed, as well as turbulent conditions with winds which varied from 5 to 20 knots.

b. The following observations were made:

(1) On high-speed runs, the core of the vortex appeared to be relatively small and did not grow to any significant extent before the smoke dissipated. It was difficult to determine the time of break-up with any accuracy, because of the limited volume of smoke dispensed over the intercept point. It was noted that any turbulence or wind hastened the break-up of the smoke pattern. The limited volume of smoke dispensed made it impossible to study the persistency of the vortices' pattern after a few seconds, even when atmospheric conditions were calm.

(2) On low-speed runs, when the aircraft was clean, and on runs with the aircraft in landing configuration, the core appeared to be larger and more violent than in high-speed runs. However, from observers' reports and from studies of motion pictures, no conclusions could be drawn as to which low-speed configuration produced the greatest wake disturbances. Under extremely stable atmospheric conditions a definite spinning motion could be observed for two minutes and traces of smoke with some evidence of vortex motion could be observed for approximately three minutes. However, with very light turbulence or winds the smoke dissipated very rapidly, and no definite conclusions could be drawn concerning the vortex history after approximately 30 seconds.

3. Vortex Penetrations.

a. Drome Penetrations.

(1) To study the effect of wing-tip vortices on lightly wing-loaded aircraft, a QL-17 was used to intercept the vortex disturbances generated by F-100 and B-47 aircraft.

Figure 10.
E-47 Passing
Under QL-17



Time interval of attempted intercepts ranged from two seconds to 120 seconds after the vortices had been generated. Three different methods of intercept were attempted:

(a) The F-100 was flown on a given course at an airspeed of 200 knots at an altitude of 1,000 feet. The drone aircraft was flown on a course which would cause it to intercept the vortex disturbances generated by the F-100. This method of intercept was unsuccessful.

(b) The drone aircraft was flown on a given course at an airspeed of 110 miles per hour at an altitude of 1,000 feet m. s. l. The pilot of the F-100 flew along side of the drone and then altered his course so that he would intercept and cross the projected flight path of the drone. The drone intercepted the vortex wake of the F-100 at angles which varied from 45 to 90 degrees.

(c) The third type of intercept was made by the F-100's overtaking, passing under, and pulling up in front of the drone.

(2) Intercept time intervals were clocked by ground observers with stop watches. Intercepts were filmed by cameramen from ground points and from a helicopter. The oscillograph recorder mounted in the drone was turned on and off by the drone-control pilot from the

drone-control station. Figures 11 and 12 list successful intercepts with data recorded. Missing data are due to lack of reaction of drone to the penetration or to a malfunction of parts of the measuring equipment.

PORTAL PENETRATION (degree)	TIME INTERVAL (seconds)	VERTICAL ACCELERATION (-an in g's)		PITCH CHANGE (degree)	ROLL (degree)	Yaw (degree)	
45	2				30R		
90	20	-0.77	+0.27	4.0 up			
60	2	-1.15	+0.57	4.5 dn	40R	3.0R	
45	2	-1.15	+0.27	7.3 dn		1.2R	
90	3	-0.77	+0.77				
90	3	-1.20	+0.65				
*	2	-0.38	+0.38	10.9 up	4.7 dn	60R	8.7R 1.5L
*	3.5	-0.72	-1.08	7.0 up	11.4 dn	70R	19.6R 1.0L
*	5.5	-0.96	+0.65		9.6 dn	5.6R	1.5R
90		-1.31	+0.60		5.6 dn		
90		-0.72	+0.48				
*	4	-1.90	+0.72	5.4 up	7.3 dn	13R	7.0R 5.1L
90	3	-1.47	+0.30	5.0 up			
45	2.5	-1.18	+0.74	4.0 up	1.7 dn		
45		-2.14	+0.64		4.7 dn		5.3L
*	3	-0.53	+0.90	2.0 up	6.5 dn	30R	
45	4	-1.30			5.0 dn		
45	3	-0.30		5.0 up			
45	14	-0.55	+0.77	5.0 up	5.0 dn		9.3L 1.0L
*	10	-0.70					
*	2	-1.05	+0.55		12 dn	10R 19.8L	1.9R
90	4	-0.29		4.0 up	3.1 dn	20R	
90	10	-1.77	+0.68	5.0 up			
45	1	-0.74	+0.15	1.5 up	3.0 dn		
*	2	-0.53	+0.74	5.0 up	1.5 dn	34L	4.7R
*	2	-0.89	+0.80	5.0 up	9.1 dn	42.2R	7.0R 3.7L
*	10	-0.5	+0.3		10 dn	13L	3.0L
*	1	-0.52	+0.97	4.0 up	9.2 dn	74L	4.7R 25L

F-100 overtook, passed under, and pulled up in front of the L-17.

Figure 11. Data Recorded by an Oscillograph During J-1 Penetrations of Wing Tip Vortices Generated by an F-100.

VORTEX PENETRATION (degrees)	TIME INTERVAL (seconds)	VERTICAL ACCELERATION ($\pm \Delta n$ in G's)		PITCH CHANGE (degrees)		ROLL (degrees)	YAW (degrees)	
45	4.5	-2.15	+0.92	8.5 dn 10.0 dn		28.9R	1.66L	
45	4	-1.31	+0.52	2.8 up	6.2 dn	35R	1.38R	2.76L
*	2	-0.96	+1.50	22 dn		13L		
*	4	-0.87	+0.60	9 up	9.7 dn			
*	1.5	-0.66	+0.30	7.7 up	3.0 dn			

*B-47 overtook, passed under, and pulled up in front of the L-17.

Figure 12. Data Recorded by an Oscillograph During QL-17 Penetration of Wing-Tip Vortices Generated by a B-47

(3) The drone was equipped with an autopilot which rapidly responded to correct any deviation of the drone from straight and level flight. The reaction of the autopilot was much faster than could be expected from a pilot and it would be difficult to draw any conclusion as to what degree of deviation from straight and level flight would have occurred had the aircraft been flown by a pilot. It should be noted that, even with the autopilot, variations up to 30 degrees of yaw and 74 degrees of roll were observed.

(4) It was the opinion of pilots and engineers who observed the drone reaction to the vortex that a pilot could not have stopped the roll before the aircraft assumed an inverted attitude or other unusual position. Had the drone been at approach speed (when aileron control is less effective), it is doubtful that even the autopilot could have stopped the roll before the drone assumed an inverted attitude.

b. Piloted Penetrations. Two flights were made in which a piloted L-19, flying at 90 miles per hour, attempted to penetrate the F-100 vortices. The F-100 was flown at an airspeed of 200 knots in landing configuration at an altitude of 6,000 feet. The F-100 dispensed smoke on each of the attempted intercepts.



Figure 12. F-100 Passing Under L-19

The smoke marking the vortices dissipated after 30 seconds, and there was no way to determine if the center of the disturbed area was penetrated. Only mild turbulence was encountered when entering the supposed area of turbulence 45 to 90 seconds after the passage of the F-100. At 45 seconds one sharp gust was felt. Letting down into the vortex 30 seconds after the F-100 had passed, the right wing of the L-19 dropped and the aircraft yawed to the right. Full left rudder and left stick were applied. The right wing nevertheless dropped approximately 50 degrees and the airplane yawed 30 degrees to the right. The pilot was unable to hold the airplane in the vortex. On other intercepts, at

time intervals of 8 to 15 seconds, no difficulty was encountered in intercepting areas of disturbances when letting down from above. The L-19 was subjected to forces which caused 50-degree rolling, 30-degree yawing, and some pitching movements, even with nearly full corrective control forces applied. There appeared to be a tendency for the vortex to force or throw the L-19 out of the disturbed area. On one occasion, the L-19 intercepted the vortex at eight seconds and remained in the disturbance for 20 seconds. Violent rolling, yawing, and pitching movements were encountered.

4. Sonic Shock.

a. To determine the effect of sonic shock on Army aircraft in flight, a QL-17 drone aircraft was set on course at 1,000 feet and subjected to sonic shock waves generated by an F-100 flown at speeds of Mach 1.0-1.05. Making approaches at supersonic speeds toward the front, side, and rear, the F-100 passed over the drone at altitude separations of 500 and 1,000 feet. To subject the drone to sonic shock from below, the passes were repeated, and the F-100 flew under the drone at altitude separations of 500 feet. On the last pass, the pilot of the F-100 overtook the drone and passed slightly above and to the right at a separation of approximately 200 feet.

b. Sonic shock waves produced under these conditions did not cause any structural damage to the QL-17. There were no visual indications that the flight of the QL-17 was in any way affected by sonic shock waves.

VI. DISCUSSION.

1. Beech Aircraft Corporation Survey.

a. Several years ago, the fatal crash of a civilian utility-type aircraft, on landing approach at a busy air terminal, prompted the Flight Safety Department of Beech Aircraft Corporation to query many pilots regarding any experience they may have had in encountering turbulence behind large aircraft. Beech received more than 200 replies from pilots of many different types of aircraft. A representative number of the replies were published in Beech Safety Suggestion Nr 8 in 1952. Since this collection is probably the most comprehensive collection of pilots' comments to be found on this subject, they are included in this report (Appendix B).

b. A significant point made by many of the pilots was that the incidents occurred when there was a definite lack of turbulence and when wind and weather were ideal for flying. The severe rolling movements reported by the pilots were encountered during these tests. Many pilots reported rolls of as much as 90 degrees when the disturbances were encountered during approaches. At low speeds, aileron controls are not as effective and slower response to corrections must be expected.

c. It was noted, during the test at Eglin, that any atmospheric turbulence caused rapid decay of vortex patterns. Under calm conditions the vortex patterns persisted longer.

2. Other Studies.

a. Wright Air Development Center, Air Research and Development Command, United States Air Force, Wright-Patterson AFB, Ohio, is initiating a study to determine the effect of turbulence on aircraft landing every 30 seconds. A study is also being made by Cornell Aeronautical Laboratory, Inc., of Cornell University. The WADC and Cornell studies are being made for the Office of the Special Assistant to the President for Aviation Facilities Planning.

b. These programs include both theoretical studies and flight tests to determine effect of turbulence on aircraft in flight. Flight tests will include a study of the effects of turbulence generated by fighter, bomber, and transport aircraft on different types of aircraft at traffic patterns and on landing and takeoff. This Board's testing was limited to intercepts of turbulence at cruising speeds. The WADC test will include intercepts at approach and landing speeds.

c. Wright Air Development Center, Air Research and Development Command, USAF, is conducting an intensive study into sonic boom problems. This study will include a comprehensive theoretical study of sonic shock phenomena and effects. The flight-test site for this program is tentatively Eglin AFB, Florida, and will include test aircraft such as the F-100, F-101, F-102, and F-104.

VII. SUMMARY.

1. The duration of wing-tip vortices is governed primarily by the turbulence structure of the atmosphere in which they are generated. Greater vortex disturbances are generated when the generating aircraft are flown at low airspeeds. Any turbulence or wind has an immediate dispersing effect on the duration of wing-tip vortices.

2. Up to time intervals of 30 seconds behind an F-100 flown in landing configuration at airspeeds of 200 knots, the vortex effect may be of such magnitude that a light airplane intercepting the disturbances could not be held in straight and level flight. If the light aircraft were at low speeds, such as approach or landing, it could become uncontrollable to such an extent that a crash could not be avoided. It is highly improbable that an airplane would remain in vortex turbulence long enough to make a complete roll. The most likely response would be to roll to an inverted or near-inverted position and be thrown out of the vortex.

3. No structural damage was sustained by the test aircraft penetrating the wing-tip vortices created by F-100 and B-47 aircraft during this test. However, based on negative loads recorded during this test, it appears possible that, under conditions of extremely stable air, light airplanes penetrating the wing-tip vortices generated by highly wing-loaded aircraft flown at low airspeeds could sustain structural damage, particularly if the lightly wing-loaded airplane was being operated at higher than normal cruise speed.

4. Sonic shock waves generated at airspeeds up to Mach 1.05 and separations as near as 200 feet did not cause any structural damage to the QL-17. There were no visual indications that the flight path of the QL-17 was in any way affected by sonic shock waves. However, it cannot be deduced from this test that light aircraft would not sustain structural damage from sonic shock waves generated by airplanes flown at speeds well above Mach 1.

5. The results of this test indicate a definite need for additional information on the effect of vortex disturbances and sonic shock on light aircraft. A comprehensive study of these problems, involving theoretical studies, engineering tests and flight tests, will be required to secure any significant information. Such studies are beyond the capability of this Board.

VIII. CONCLUSIONS.

1. In regard to the duration, characteristics, and intensity of wing-tip vortices:

a. The duration is governed primarily by the atmospheric conditions existing. Any air disturbance has an immediate dispersing effect.

b. The greatest disturbances produced by any aircraft occur when that aircraft is traveling at low airspeeds, such as in landing and takeoff patterns.

c. No quantitative conclusions could be reached on intensity; however, the vortex effect can be of such intensity that a serious control problem will be created when light airplanes encounter the disturbances at low airspeeds.

2. Wing-tip vortices can produce momentary loss of control to Army airplanes and could under certain conditions produce structural damage to light airplanes.

3. Further tests and studies, by agencies capable of more comprehensive investigation than this Board, should be made of the effects of sonic shock and wing-tip vortices on Army aircraft.

IX. RECOMMENDATIONS. It is recommended that:

1. The US Army monitor the study and flight-test program being initiated by Wright Air Development Center, Air Research and Development Command, USAF, to study the effect of turbulence on aircraft landing every 30 seconds.

2. The US Army monitor the sonic boom program being initiated by Wright Air Development Center, Air Research and Development Command, USAF.

3. The US Army support further investigation of the sonic shock and wing-tip vortices problems to the extent necessary to determine effects on Army aircraft.

X. REFERENCES.

1. NACA TN 3377 "Flight Measurements of the Velocity Distribution and Persistence of the Trailing Vortices of an Airplane."
2. Douglas, Santa Monica, Report SM-18647 "Theoretical Analysis of Light Plane Landing and Take-off Accidents Due to Encountering the Wakes of Large Airplanes."
3. Royal Aircraft Establishment - T. N. No. AERO. 2383 "A Flight Investigation of the Wake Behind a Meteor Aircraft."
4. Flight Safety Foundation "Pilots' Safety Exchange Bulletin 55-104."
5. A.F.P.T.C. - TN-56-20 "A Flight Test Investigation of the Sonic Boom."
6. WADC-TN-55-203 "Experimental Investigation of the Shock Wave Pressure Characteristics Related to the Sonic Boom."
7. Beech Safety Suggestion Nr 8, 1952.
8. Beech Aircraft Corporation, "Evaluation Report, Effect of Wing Tip Vortices and Sonic Shock on Army Aircraft in Flight."

X. COORDINATION.

1. Plan of Test.

a. The Tentative Plan of Test was prepared by this Board and circulated to other interested agencies for comments. Their replies, and comments by this Board, are consolidated below:

(1) The Chief of Transportation.

STATEMENT: "1. The subject "Draft Plan of Test" has been reviewed and appears to be very complete and comprehensive. This office has no recommendations to make at this time concerning the plan as proposed or concerning additional test which may be desirable."

BOARD COMMENT: Noted.

(2) The Canadian Army.

STATEMENT: "2. The draft plan of test has been studied and the following comments are submitted by the Canadian Army:

"(a) It is suggested that tests should not be limited to specific high wing loaded aircraft but include the vortex generating characteristics of high speed jet aircraft manoeuvring in such a manner as to produce their CL(Max)." "

BOARD COMMENT: This Board concurs. However, only F-100 and B-47 Jet aircraft are available for test program. These aircraft will be flown at low airspeeds (high C_L) during test.

(3) The following agencies concurred in the Tentative Plan of Test:

(a) The Marine Corps Development Center.

(b) The Army Maintenance Board.

(c) The Air Proving Ground Command.

(4) The British War Office, through the British Liaison Officer, replied, but had no comment to make on the Tentative Plan of Test.

b. No reply has been received from the Chief Signal Officer on the Tentative Plan of Test.

2. Report of Test.

(a) The Tentative Report of Test was prepared by this Board and circulated to other interested agencies for comments.

The Marine Corps Development Center concurred in the Tentative Report of Test.

(b) No reply has been received from the following agencies on the Tentative Report of Test:

- (1) The Chief of Transportation.
- (2) The Chief Signal Officer.
- (3) The British War Office, through the British Liaison Officer.
- (4) The Canadian Army, through the Canadian Liaison Officer.
- (5) The Air Proving Ground Command.
- (6) The Air Research and Development Command.

APPENDIX A

EVALUATION REPORT

EFFECT OF WING-TIP VORTICES AND SONIC SHOCK

ON ARMY AIRCRAFT IN FLIGHT

This appendix contains an extract of Beech Aircraft Corporation's report of a preliminary study of oscillograph records obtained during this test.

Beech Aircraft Corporation

EVALUATION REPORT

**EFFECT OF WING TIP VORTICES AND SONIC SHOCK
ON ARMY AIRCRAFT IN FLIGHT**

January, 1957

W. J. SMITH JR.
Military Service-Technical Representative

CHASE J. KING
Quality Control Engineer

BEECH AIRCRAFT CORPORATION
Wichita 1, Kansas

FOREWORD

This report is essentially an addition to the "PRELIMINARY STUDY OF THE EFFECT OF JET BLAST OR WAKE ON OTHER AIRCRAFT" issued by the Flight Safety Section of the Quality Control and Customer Service Division of Beech Aircraft Corporation, under the direction of Mr. P. E. Allen.

As a result of correspondence between Mr. M. J. Fortner, civilian Aeronautical Engineer, of the United States Army Aviation Board, and Mr. Allen, Beech Aircraft Corporation participated in the Army Aviation Board tests conducted at Eglin AFB, Florida. This report is based on observations, comments of participating Military Personnel, and oscillograph data obtained during the tests.

The Beech Aircraft Corporation personnel, who participated in the program, are particularly grateful to the United States Army Aviation Board for the privilege of participating in the tests and of working with the Army Officers, enlisted men, and civilian Board Members assigned to the project. Especially, we would like to express our appreciation to Captain Robert L. Head, Project Officer, and Mr. M. J. Fortner, Technical Advisor, of the Army Aviation Board, and Captain Roscoe Tanner, AFOTC Project Officer.

EVALUATION REPORT

Effect Of Wing Tip Vortices And Sonic Shock On Army Aircraft In Flight

PURPOSE OF REPORT

This report is a preliminary study of the oscillograph records obtained during the United States Army Aviation Board tests (Project No. 2656) conducted in conjunction with the Air Force (APG/TAT/1293-A) at Eglin AFB, Florida. Some of the data emphasizes that additional research is required and this is discussed as part of the report. The experience of participating in these tests was very beneficial and worthwhile as it pointed out the problems to be overcome and suggested equipment changes that would aid in any further research.

CONCLUSIONS

In drawing any conclusions, consideration must be given to the limitations of the recorded data, but the following items were tentatively established during the tests.

1. Vortices Penetrations

- a. Negative load factors higher than the minimum ultimate design requirements for Normal Category personal aircraft can reasonably be expected at higher cruise speed, since at the low drone speeds and high generating aircraft speeds, an load factors of -2.0 g's were recorded.
- b. In the opinion of experienced Army pilots flying the L-23 Mother Ship and observation planes, Normal or Utility Category aircraft attempting take-offs or landings and encountering rolling, yawing, and pitching of the magnitude experienced by the QL-17 would be lost.
- c. Every change in attitude of the QL-17 resulting from vortex penetrations would have been more severe for a piloted Navion than for the QL-17 controlled by the autopilot.
- d. Though not established by penetrations, observation of smoke runs prior to the arrival of the QL-17s, indicated that the 30-second separation interval for the WADC ILS proposal would create a flight hazard on calm days. The Air Force pilot flying the B-47 vortex generating plane stated that vortices presented a control problem when one B-47 followed another in landing, and a light aircraft following at a 30-second separation would many times be in a hazardous area.

2. Sonic Shock Tests

- a. The tentative information from the shock wave tests was that it is possible to hit an airplane of the Navion type with a shock wave shed at Mach 1.02 at a distance of approximately 500 feet without causing a structural failure. Attention is called to the fact that Mach 1.02 is very nearly Mach 1.0 at which only local shock waves are present and

2. Sonic Shock Tests (Continued)

that shock waves created by planes flying at Mach 1.5 to 2.5 would be many times as severe as those encountered during the tests. The data recorded during this phase of the test requires additional information on the QL-17 characteristics before any attempt at evaluation can be made.

- b. It can safely be concluded, however, that a car window can be broken by flying an F-100 over it at sub-sonic speed and cutting in the afterburner which probably produced local pressure waves. This actually happened as a side light of the tests.
- c. Though not a result of these tests, it has been established at Eglin AFB and the surrounding area that sonic booms need further study as a result of claims for damaged roofs, church steeples, walls and windows. It is concluded that additional research as to their effect on planes in the air and on the ground is advisable.

RECOMMENDATIONS

The Army Aviation Board tests definitely point out that there are many areas of potential hazard from wing tip vortices and from sonic shock waves generated by many of today's aircraft. It is recommended that an extensive program be instigated to establish the following:

- 1. The velocity distribution of the vortices, the duration of the turbulence, and the displacement and dispersement of the vortices with time and/or wind conditions.
- 2. Safe separation intervals between aircraft, landing and taking off, based on wind conditions and types of airplanes.
- 3. Safe separation distances (vertical and lateral) between vortex generating planes and vortex penetrating plane.
- 4. Danger areas for light aircraft operating in range of supersonic aircraft.

DISCUSSION

Theory indicates that low speed and high wing loads for a vortex generating plane will produce the highest load factors and/or greatest rotational (pitching, rolling, yawing) acceleration on the penetrating plane.

The speed (200 knots) and weight (approximately 30,000 lbs.) of the vortex generating plane and the speed (110 mph) of the vortex penetrating plane were not expected to produce destructive loads, but from the data obtained it was anticipated that sufficient confirmation of equations suggested by previous studies could be determined to show by extrapolation that destructive loads for light commercial aircraft can reasonably be expected.

The data obtained from the tests was limited for several reasons and it is felt that it would be well to point out these limitations and include suggestions for additional research. Experience gained from these tests indicate that additional studies would be extremely desirable.

The time element in preparing for these tests ruled out the use of strain gages on the drone and it is felt that this omission left much to be desired in determining stress distributions from the loads imposed by the penetrations.

The autopilot response was so rapid that a comparison between the drone reaction and the reaction of a piloted aircraft was extremely difficult.

The growth of the vortex diameter with time remains as something of a question. Photographic coverage of the vortices presented unexpected problems, which could be corrected by assigning personnel familiar with what was desired, and by having all necessary equipment available to assure good coverage of the vortex movements. Wind tunnel tests using a screen with tufts to outline the vortex would be beneficial in answering these questions.

The location of the smoke tanks was such that although the vortices are completely rolled up in a fraction of a second, the outboard tanks were the only two of the six that would consistently show the expected rolling turbulence of the vortices. Ejection of the smoke at the wing tips would be extremely beneficial. As pointed out in two other studies, one of the major problems is hitting the vortex center; this was again born out in these tests where a number of passes resulted in complete misses.

The date limit set for these tests did not permit nearly as many flights as required for thorough study. Flights were cancelled because of excessive winds, gusts, rain, fog and maintenance problems. A test program set up for a definite number of flights rather than a time limit is suggested to assure a realistic study of vortex effects.

The altitude control of the drone was partly responsible for the difficulty in vortex penetration. The drone altitude varied with the pressure variations and these changes caused some of the misses. A more stable altitude control or suitable method of piloting the drone through the vortices is required.

While the very first inspection of the proposed flight test program indicated that the loads to which the drone would be subjected upon penetration of the

Discussion (Continued)

vortices would be fairly small in magnitude, it was the intent of the Beech Engineering Department to check the correlation of calculated loads with those measured during tests so that reasonable reliance could be placed upon analytical values determined for more severe conditions.

The analytical approach to the problem has no way of accounting for the wind velocity and gust conditions and also is based on the assumption that the penetration occurs at the center of the vortices.

An investigation of the calculated and measured values shown on Page 9 shows fair correlation in some cases and extremely poor in others. It is the opinion of the Engineering Department that the poor correlation is due to the wind and gust conditions and to missing the vortex centers.

The tests definitely indicate the necessity of a more closely controlled program in regards to the wind velocity and gust effects and means of insuring penetration of the vortex at the center.

The records for Mission 9 were not plotted as the oscillograph record was questionable. Delta "n" for Mission 10 was not calculated as the weight was not recorded for the F-100 during the flights. The oscillograph records for Missions 11, 12, 13, 14, 15 and 19 were used to furnish measured Δn readings to compare with the calculated ones.

The maximum positive and negative readings recorded during the tests are tabulated on Page 8.

The "Proposal" and "Conclusions" included at the end of the report are based on individual studies of the problem by Beech Engineers.

DATA ON TEST AIRPLANES

QL-17 (1344)

Wing Area - 184 ft.²

Max. Weight - 2514.5 lbs. (Assumed average weight - 2450 lbs.)

Wing Span - 35.417 ft.

C.G. Location (2450 lbs.) - Fus. Sta. 100.85

Accelerometer Location (Vertical) - Fus. Sta. 93.125 (7.725 in. fwd. of C.G.)

QL-17 (1346)

Same as 1344

F-100 (625)

Gross Weight (L) - 25534 lbs. plus Fuel*

Wing Span - 40 ft.

B-47

Gross Weight (L) - 84500 lbs. plus Fuel*

Wing Span - 116 ft.

L-19

Max. Weight - 2430 lbs.

Wing Span - 36 ft.

Wing Area - 174 ft.²

*Weight of fuel before each pass recorded by generating plane pilot.

CALCULATIONS FOR CHANGE IN LOAD FACTOR (Δn)

The core radius (y) used in the calculation of Δn is measured from the vortex velocity distribution of the F-100 and the B-47. This distribution is calculated from data given in NACA TN 3377. These velocities are based on an IAS of 150 mph. The core radius (y) is assumed to remain constant, with the weight and velocity of the generating planes variable.

The basic equation, $\Delta n = (KV\phi/w/s)(2L/\pi^2 b\phi U) [1 - e^{-Z}]$ where $Z = y^2/4\phi t$, is simplified by the following assumptions, $K = 1.0$, and e^{-Z} is a negligible quantity. This results in $\Delta n = [V/w/s] [2L/\pi^2 b\phi U]$

Where Δn is the change in penetrating load factor

V is the penetrating plane flight speed (161 ft/sec)

w/s is penetrating plane wing loading (2450/184 or 13.32 lb/ft²)

b is the span of generating plane (F-100 is 40 ft, B-47 is 116 ft)

y is $\frac{1}{2}$ the distance from max. upward velocity to max. downward velocity.

(F-100 = 8.5/2 or 4.25 ft., B-47 = 26/2 or 13 ft. — Ref. velocity distribution curves for F-100 and B-47 on Page 10.)

U is the velocity of the generating plane (ft/sec) = knots x 1.152

x 1.467 = knots x 1.69

L = lift of vortex generating = nW

n = generating plane flight load factor

W = weight of generating plane (F-100 = 25534 lbs. plus fuel -

B-47 = 84500 lbs. plus fuel)

Then for F-100

$$+\Delta n = (161/13.32) (2L/3.14^2 \times 40 \times 4.25 \times U)$$

$$-\Delta n = (161/13.32) (2L/3.14^2 \times 40 \times 4.25 \times U) + (161/13.32) (2L/3.14^2 \times 40 \times 35.75 \times U)$$

$$+\Delta n = .01442 L/U$$

$$-\Delta n = (.01442 + .00172) L/U = .01614 L/U$$

For B-47 (The B-47 weight at each pass was calculated and recorded by the pilot)

$$+\Delta n = (161/13.32) (2L/3.14^2 \times 116 \times 13 \times U)$$

$$-\Delta n = (161/13.32) (2L/3.14^2 \times 116 \times 13 \times U) + (161/13.32) (2L/3.14^2 \times 116 \times 103 \times U)$$

$$+\Delta n = .001626 L/U$$

$$-\Delta n = (.001626 + .000205) L/U = .001831 L/U$$

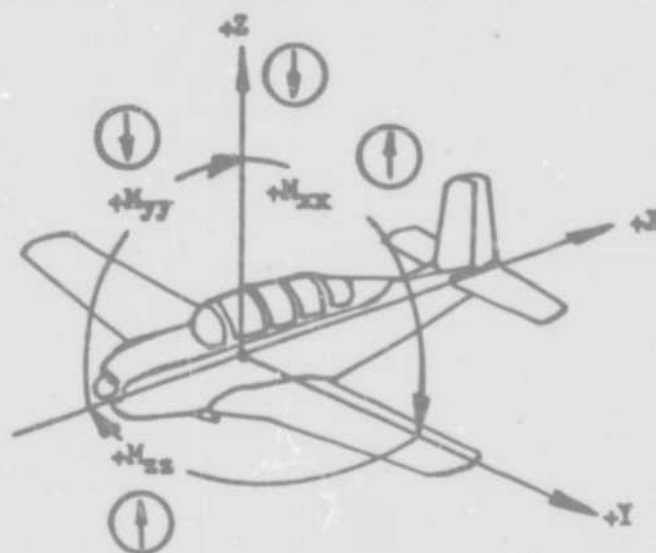
OSCILLOGRAPH DATA

Mission No.	Ch'nl No. 1 Vert. Acc g's/in.	Ch'nl No. 5 Pitch Att. Deg/in.	Ch'nl No. 6 Roll Att. Deg/in.	Ch'nl No. 7 Yaw Att. Deg/in.	Ch'nl No. 8 Airspeed mph/in.	Ch'nl No. 9 Altitude ft/in.	Ch'nl No. 10 Roll Att. Deg/in.
9	3.83	9.70	15.2	14.5	9.9	101	—
10	3.83	9.70	15.2	14.5	9.9	101	—
11	3.61	15.6	—	14.0	17.25	175	19.35
12	3.61	15.6	—	14.0	17.25	175	19.35
13	2.95	15.6	—	14.0	17.25	175	48.6
14	2.78	15.6	—	14.0	17.25	175	48.6
15	2.96	15.6	—	14.0	17.25	175	48.6
16	2.96	15.6	—	14.0	17.25	175	48.6
18	3.40	14.2	51.9	13.8	21.3	200	—
19	4.38	14.2	51.9	13.8	21.3	200	—
22	2.85	15.6	—	14.0	17.25	175	48.6

Maximum Oscillograph Readings

(1)	(2)	(3)	(4)	(5)
Movements Recorded	Mission And Pass	Maximum (Positive) See Sketch	Maximum (Negative) See Sketch	Net Change (3)-(4)
Acceleration (Vert.)	13-3-2	Trace Down- .35 g's	Trace Up- 2.00 g's	2.35 g's
Pitching	19-6	Trace Down- 3.75°	Trace Up- 10.00°	18.75°
Rolling	19-8	Trace Up- 74.00°	Trace Down- .00°	74.00°
Yawing	19-8	Trace Up- 5.00°	Trace Down- 26.00°	31.00°

⬆ Indicates trace direction for "Positive" Measurement.



(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Mission - Pass - Run	Gen. Plane Gross Wt. (Pounds)	Gen. Plane Velocity (Ft./Sec.)	L/U = (2) (3)	+Δn .001626 x (4)	- Δn .001831 x (4)	Δn Measured	
						Pos.	Neg.
19-3-1	126000	279	451.61	.73	.83	.7	-2.0
19-4-1	124700	279	446.95	.73	.82	.5	-1.2
19-5-1	122700	267	459.55	.75	.84	1.3	-.9
19-6-1	121100	262	462.21	.75	.85	1.2	.85
19-7-1	120000	254	472.24	.77	.87	.3	-.6

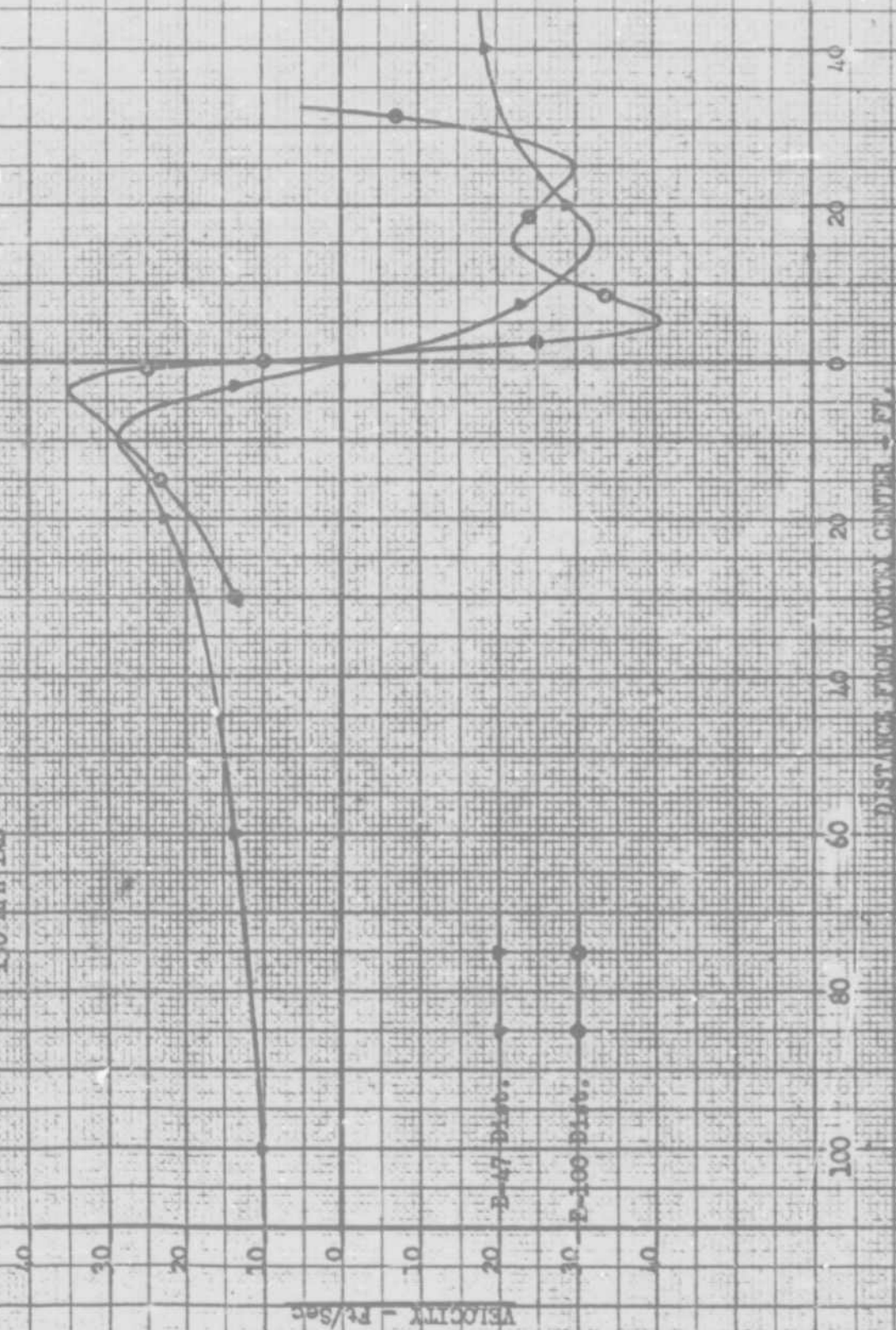
Mission - Pass - Run	Gen. Plane Gross Wt. (Pounds)	Gen. Plane Velocity (Ft./Sec.)	L/U = (2) (3)	+Δn .01442 x (4)	- Δn .01614 x (4)	Δn Measured	
						Pos.	Neg.
11-4-1	28834	338	85.308	1.23	1.38	.95	.75
11-5-1	28535		84.423	1.22	1.36	.6	.9
12-1-1	31134		92.112	1.33	1.49	.5	1.15
12-1-2	29934		88.562	1.28	1.43	.7	1.05
12-6-1	29034		85.899	1.24	1.39	.95	1.70
13-2-2	30834		91.225	1.32	1.47	.6	1.30
13-3-2	30334		89.746	1.29	1.45	.45	2.0
13-3-1	30534		90.337	1.30	1.46	.70	1.0
13-6-1	29134		86.195	1.24	1.39	1.00	.5
14-3-2	30234		89.450	1.29	1.44	.20	1.3
14-4-2	29734	338	87.970	1.27	1.42	.65	.65
14-4-1	29934		88.562	1.28	1.43	.20	.35
14-5	29334		86.787	1.25	1.40	.15	.80
14-6	29034		85.899	1.24	1.39	.40	1.15
15-1-1	31334		92.704	1.34	1.50	0	.4
15-2-2	30734		90.929	1.31	1.47	.6	1.6
15-3-1	30434		90.041	1.30	1.45	.2	.7
15-5-1	29634		87.675	1.26	1.42	.7	.5
15-6-1	28934		85.604	1.23	1.38	.8	.8
15-6-2	28734		85.012	1.23	1.37	.4	.6
19-8	26340	279	94.409	1.36	1.52	.6	.6

COMPARISON - CALCULATED Δn WITH MEASURED Δn

WAKE VELOCITIES OF P-100 AND B-47

Based on NACA TN 3377

150 MPH TAS



BEECH AIRCRAFT CORPORATION
Inter-Office Communication

January 9, 1957

FROM: T. L. Maltby
TO: Ernest Utter
CC: D. E. Burleigh, P. E. Allen, C. H. Prewitt, W. G. Pierpont,
C. J. King
SUBJECT: Conclusions Drawn from an Observation of the Wing Tip Vortices and
Sonic Shock Tests Designated Army Project No. 2656

In addition to the problems enumerated in the previous memos, an observation of the flight tests indicated three additional critical problems if any correlation between the theory and flight tests is to be obtained. These factors are:

1. Vortex Core Diameter
2. Axis of Penetration of the Vortex
3. Wind Effect

I Vortex Core Diameter

It is suggested that an estimation of the vortex core diameter might be obtained in the following manner. Place a tufted grid aft of the model during the tunnel tests. The direction of the tufts should indicate both the diameter of the core and the vortice. By moving the grid aft and repeating the tests, the increase in these diameters could be evaluated. A time history of this growth could be obtained by correlating the distance of the grid aft of the tip with the tunnel flow velocity.

II Axis of Penetration of the Vortex

It is the opinion of the writer that theodolite data might be used to locate the tip of the vortex-generating aircraft in space and the exact altitude at which the drone penetrates this vortex. It is important to know whether or not the drone penetrated the center of the vortex or only encountered the outside fringes.

III Ambient Wind Velocity and Gust Intensity

An observation of the behavior of the smoke generated during the tests indicates that the atmospheric wind velocities and gust intensities have a very significant effect on the vortices. There does not appear to be a very good solution to this phase of the problem, and the only recommendation apparent to the writer at this time is to gather statistical data of the time for the vortices to break up as a function of the wind velocity and gust intensities and limit the penetration tests to conditions when the wind and gust velocities do not exceed certain limiting values.

BESCH AIRCRAFT CORPORATION
Inter-Office Communication

January 9, 1957

Subject: Conclusions Drawn from an Observation of the Wing Tip Vortices and
Sonic Shock Tests Designated Army Project No. 2656 - Page 2

IV Conclusions

The flight tests conducted during the aforementioned project definitely established the existence of significant disturbances and pointed out the magnitude of the problems, not apparent from the theoretical investigation, encountered in a flight test program to evaluate these effects.

A very careful study and scheduling of a program would be necessary in order to properly evaluate these effects.

T. L. Maltby

T. L. Maltby
Structures Engineer

TLM:th

APPENDIX B

BIG PLANE TURBULENCE CAN

CAUSE A FLIGHT HAZARD

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SAFETY SUGGESTIONS

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BIG PLANE TURBULENCE CAN CAUSE A FLIGHT HAZARD

This was tragically brought to our attention with the fatal crash of a Bonanza on its landing approach at a busy air terminal. As a result of this accident we asked for resumes of the experience that pilots may have had in encountering turbulence in landing behind large aircraft.

The hundreds of answers which we received to this question prove that there is a flight hazard in the traffic pattern and that there is a definite need for a study of the air traffic control procedures now in effect to provide more protection for flight in the controlled traffic patterns.

What Causes This Hazard? Basically it is (a) the wing tip vortexes and (b) the swirling propeller wash of large aircraft that creates a turbulence which can upset another aircraft, as indicated in Figures 1 through 5 of this bulletin.

What Type of Airplanes Does This Affect? The answer is all types. Replies to our inquiry show the following types of aircraft have been seriously affected by landing turbulence, according to more than 200 letters from their pilots:

Model 35	North American
(BEECHCRAFT)	AT-6

Stinson	Douglas B-26
Cessna 140	Vought Corsair
Cessna 170	Swift
Cessna 190	Ercoupe
Cessna 195	DC-3
Navion	Beech C-45
Piper Cub	Waco
Piper Tri-Pacer	Beech Model 18
Lockheed Lodestar	Aeronca
Douglas A-20	

What Type of Planes Are Reported to Have Caused This Turbulence? Pilots have reported severe or dangerous turbulence caused by varied types of aircraft during their landing or take-off operation, but the most frequent and severe examples were reported behind the largest commercial airliners such as DC-6's, Constellations, DC-4's and DC-3's in that order of frequency.

Let The Pilots Tell It.

"Switzerland

"First days of October, 1951, I took off with my Bonanza from Zurich, Switzerland, Airport. It was a beautiful evening and the air was absolutely calm. About a minute ahead of me, a four-engined transport had also taken off, but when the tower cleared me it was already out of my field

NO. 8 - SAFETY SUGGESTIONS

BEECH AIRCRAFT CORPORATION

of vision. Take-off was as smooth as can be and the usual procedure of retracting landing gear and adjusting flaps and propeller rapidly completed. Then suddenly and without the slightest warning, the Bonanza made a vertical bank. Applying full ailerons I brought her again level, but immediately the same thing happened again. There seemed no explanation for this strange behavior and there was not much time to think, as the end of the runway approached fast and the village of Klotten loomed ahead. My altitude was approximately 90 feet, when for the third time in succession the Bonanza went again on her wing. I felt there must be some mechanical defect in the controls, as I was unable to hold her. I, therefore, cut

the gas and made a belly landing at the fringe of the airport.

"I have about 2000 flying hours and flew with my glider in the roughest thunderstorms. But this was an entirely new experience. I did not feel any gusts or turbulence whatsoever. In smooth climb at about 90 miles an hour, the Bonanza seemingly went out of control for no apparent reason.

"Dozens of times have I taken off at the same distance and nearer behind large similar aircraft. Yet I never ran into any turbulence and never have considered such violent effect on my aircraft possible. I understand, however, that particu-

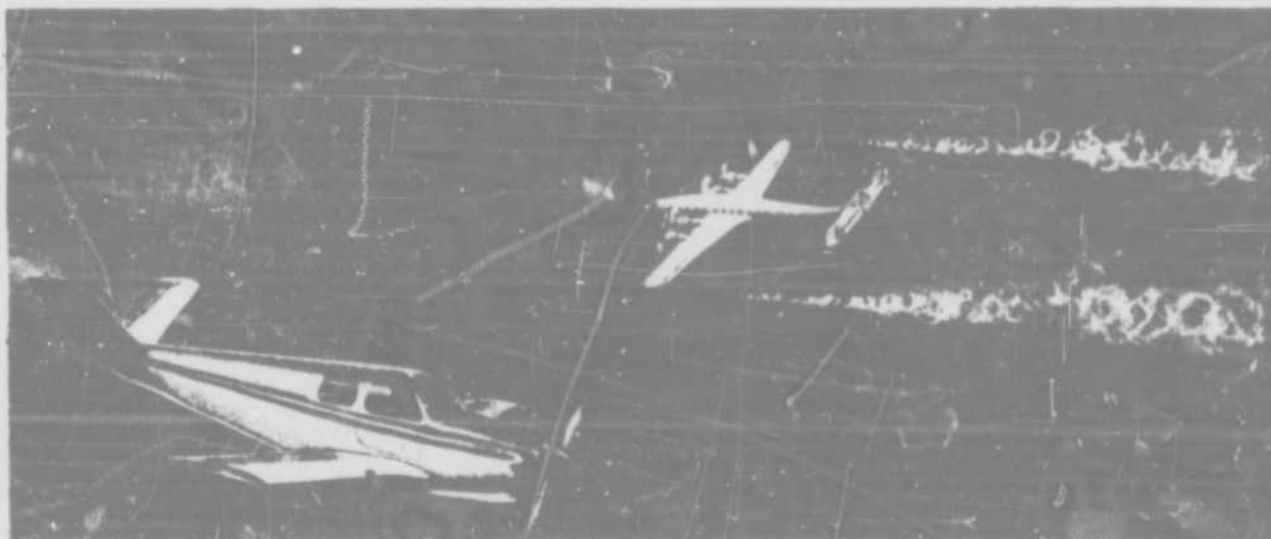


Figure 1

This figure shows the tip vortexes and swirling propeller wash trailing behind a large aircraft on its landing approach and a plane in the downwind leg of the traffic pattern.

NO. 8 - SAFETY SUGGESTIONS

BEECH AIRCRAFT CORPORATION

larly on a perfectly calm evening with no wind and no thermals the turbulence caused by a large airplane continues to loom for a considerable time dangerously over the airfield.

"I hope my experience may serve as a warning to other pilots in a similar occurrence.

Signed: M. Schachenmann"

"Salina, Kansas

"I was piloting a B-17 during a routine night landing, spaced approximately one mile behind another landing B-17, when I encountered prop wash at about 100 feet altitude and perhaps 100 yards short of the landing runway. The turbulence was so severe the landing was abandoned and

full power immediately applied. The aircraft was thrown into a nearly vertical bank, and required full opposite rudder and aileron for seemingly several seconds before positive control of the aircraft was regained. The turbulence was so severe that I'm sure the aircraft would have been damaged, had the landing been completed in this turbulence.

Signed: Fred L. Roscoe"

Florence, Alabama

"While approaching the Birmingham Airport on a clear, calm day I was authorized to follow a DC-6 into the traffic pattern with my Stinson. Of course the DC-6 had flaps and wheels down and when I entered the pattern at a point about a mile behind the DC-6, I experienced the most



Figure 2

This figure shows the large plane taxiing up to the terminal and the plane that was on its downwind leg now on its final approach for landing and entering the area of turbulence set up by the large airplane that had landed. This turbulence may remain in an area of approach for several minutes depending on the air conditions.

NO. 8 - SAFETY SUGGESTIONS

BEECH AIRCRAFT CORPORATION

violent turbulence in my flying experience. The Stinson went through a negative acceleration first, followed immediately by a positive acceleration which threw us into a steep bank and strain on the structure was sufficient to open both doors. Close examination of the plane after landing revealed no damage. The distance behind the DC-6 at the time of the incident may have been greater than one mile but not more than two, I am sure.

Signed: W. O. Perritt, Jr.
Perritt Chevrolet Co, Inc."

"El Paso, Texas

"We have had numerous instances of extremely turbulent air being encountered on landing approaches behind multi-engined aircraft. About six months ago I was making an approach in a Piper Tri-

Pacer (with a student at the controls) behind an American Airlines DC-6. The DC-6 had already turned onto a taxi strip when we were getting ready for a touchdown. About 25 feet in the air we felt we had hit a brick wall and the plane tried to turn over on its side. Both of us struggled with the controls and turned the airplane off to the right side of the runway and applied power to climb and go around. We again encountered turbulent air off to the right of the runway and at an altitude of 50-100 feet for about 500-750 along the runway before we were clear.

"Nearly every one of the six commercial pilots flying for us have experienced the same thing as mentioned in the above instance at one time or another. We are generally anticipating such turbulence now and if we make an approach close



Figure 3

This figure shows the landing airplane being upset by the turbulence.

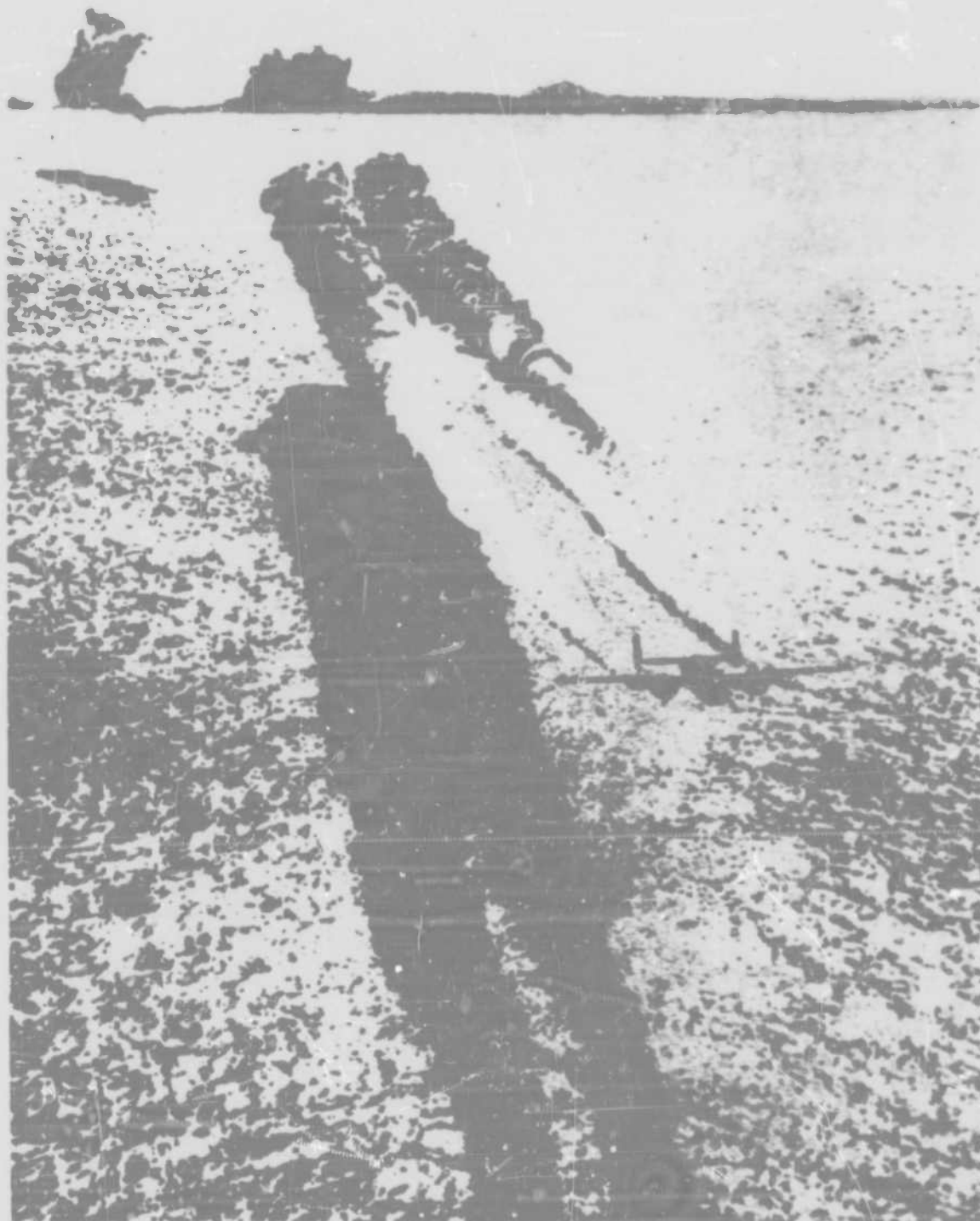


Figure 4

The trailing wing-tip vortices of a B-25 Mitchell pick up a smoke screen being laid in the Southwest Pacific.

NO. 8 - SAFETY SUGGESTIONS

BEECH AIRCRAFT CORPORATION

enough behind a multi-engine airplane, usually stand by prepared for action and hold 10-15 miles per hour extra speed until we are sure everything is OK.

Signed: William E. Mueller, Manager
Southwest Air Rangers"

"Portland, Oregon

"Coming in from Seattle one morning I was cleared by the tower to make a landing on runway 11 of the Portland Columbia Airport. As I was making my base leg approach, a DC-6 was touching down ahead of me. This was in the morning and it was fairly cool. Approximately 100 yards from the spot where I would have normally touched down and at an indicated speed of 75 miles per hour in a Ryan Navion I hit a turbulent spot in the air which caused one wing to drop quite suddenly and the

airplane to fall off to one side and drop approximately 40 feet so that the left wing nearly hit the runway before I was able to gain control of the airplane. About 10 feet above the runway the controls began to take effect, and I was able to level out and make a normal landing. If I had been coming in on my final approach at a slower speed or closer to the runway in that certain area, this turbulence could have very easily caused a crash landing. As I stated before, the air was very calm, and there was no turbulence in flying whatever. I would estimate the temperature to be between 40 degrees and 45 degrees.

Signed: J. B. Conway"

"Louisville, Kentucky

"As I turned the final in my Bonanza, I

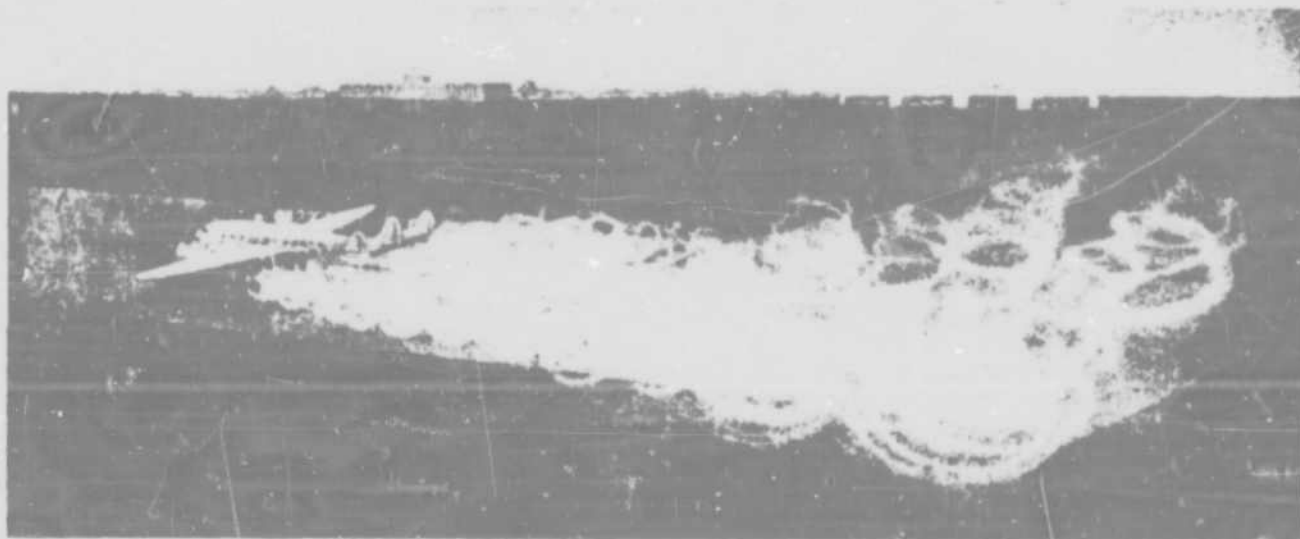


Figure 5

Vertical vortices caused by slip stream

NO. 8 - SAFETY SUGGESTIONS

notified the tower I was on final and they instructed me to land. At the moment the C-46 was still in his landing roll and I asked the tower if they were going to get him out of the way promptly. They came back in the affirmative - that he would be turning left at the end of runway. By the time he ran the runway I was over the boundary, off the field about 100 feet - wheels down, flaps down - slight power on approach - speed 90 miles per hour (not a bit less). When I had reached an altitude of about 80 feet and about 200 feet off the end of the runway - suddenly without warning my airplane completely fell out from under me. It didn't have the feeling of a stall. There was no vibration. The stall warning indicator did not register an alarm. The airplane purely and simply quit flying. I immediately with the palm of my hand hit the throttle - the motor already developing some power - the power glide responding instantaneously - the airplane fell - I would judge about 40 or 50 feet... the left wing went down slightly before the power was applied. When I applied the power I dropped the nose and a recovery was made. I went around again and made a normal landing.

Signed: R. D. Ezell
Executive Vice President &
General Manager
Roy C. Wayne Supply Company"

"Akron, Ohio

"In one particular instance, during a landing at Washington National Airport, in our

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Company Lockheed Lodestar, I was coming in at approximately 1000 feet behind a DC-3 at an altitude of about 200 feet, and during this approach, I got into prop wash of the other aircraft. The Lodestar encountered very severe turbulence behind this aircraft to the extent that the Lodestar was thrown into a lateral attitude of more than 60 to 70 degrees in an abrupt manner. It came very close to upsetting me.

Signed: Sam A. Merrill, Pilot
The Goodyear Tire & Rubber
Company, Inc."

"Guthrie, Texas

"I experienced this turbulence once on a landing at Love Field in my Cessna 190. I was working my approach on Runway 9, was cleared by the tower when a DC-6 started its take-off roll on runway 17. Not having experienced such turbulence before, I aimed to touch in where the two runways intersect on the northwest corner of the field. Fortunately, I overshot and was about 40 feet high on crossing the intersection. The DC-6 was about 2000 feet down the runway, but its turbulence rolled my plane into almost a 90-degree bank toward the DC-6. Fortunately I still had enough forward speed to right the plane with the aid of engine torque. Since then I just don't go anywhere near a big airplane.

Signed: R. B. Masterson III"

"Irvington, New Jersey

"With full gas tanks, one passenger and

NO. 8 - SAFETY SUGGESTIONS

BEECH AIRCRAFT CORPORATION

approximately 50 pounds of baggage aboard our Cessna, we were cleared from the ramp to runway 27, the longest and largest at Pittsburgh. Cleared in front of us was a TWA L749 Constellation, which like ourselves was westbound. We were cleared for take-off when the Connie was approximately 3500 feet down the runway. We suddenly encountered a severe gust, which, for some unexplainable reason, threw us into a 90-degree left bank in a fraction of a second (or so it seemed at the time). Luckily, full power was still being developed by the engine and quick aileron control coupled with a decisive right rudder action set us level before our high angle of bank, low speed combination could cause a stall. After righting the airplane, a normal climb-out resulted, no further turbulence being encountered.

Signed: John L. Lee, Asst. Sales Manager
Red Devil Tools"

"La Grange, Illinois

"About the middle of last October I had an experience which I think may aid you in your research. About sundown, I was leaving on a trip in a Cessna 140, from Chicago Municipal Airport. There was a lot of heavy traffic at the time and the boys in the control tower were getting a real workout. Just before they cleared me to take off they cleared a Connie in to land on 22L which was the runway I was to take off on. They told me to take off even before the Connie had cleared the runway, and although I called them

back and requested a little time for the turbulence to quiet down, they said they were busy and I was holding up too much traffic. As I started down the runway everything seemed normal and I went into a climb as I always did. After reaching an altitude of about 100 feet the stall warner suddenly blew and the ship was violently thrown into an extremely nose-high attitude and at the same time was rolled over so that the wings were almost vertical with the ground. The stall warner was blowing constantly and no amount of control movement made the slightest difference, the ship was completely out of control and was falling on the right wing. There were several other wild gyrations and jolts that seemed as if they were going to tear the safety belts and then suddenly about 10 feet above the ground and about 50 yards off the runway to the right everything cleared up and the ship started to fly again. From then on it was all normal and nothing more happened. The whole thing probably only took about five seconds, but it sure was a miserable five seconds.

Signed: George W. Zastrow
Dostal Excavating"

"Longview, Washington

"Recently I followed an Army twin fan job to the end of the runway and gave him what I thought to be a more than adequate start of about 1500 feet before opening the throttle on my Stinson 165. I was about 40 to 50 feet up when my plane tried (and nearly did) a snap roll to the right. Obser-

NO. 8 - SAFETY SUGGESTIONS

vers said my wings were vertical with about 12 feet of clearance from my right wing tip to the ground.

Signed: B. Davids
Davids Motor Company"

Catasauqua, Pennsylvania

"About a year ago I flew to Washington, contacted the tower there, and was advised that I was No. 2 to land in our Navion, following a DC-6. The DC-6 landed and was at the extreme end of the runway at the National Airport. Then the tower called me and suggested, if I wished, I could use another runway. I declined and continued my approach. As I was just about to cross the boundary on my final, there was another DC-4 holding in a warm-up position. When I crossed the boundary, I was approximately at 400-500 feet. At this moment a terrific down draft, the result of the prop wash of the DC-6 which was at the end of the runway, started to pull me down and flipped my plane over to the left. Fortunately I had the propeller in high rpm position with my hand on the throttle - gave it full power and followed the turn to the left, which I was then in. In a second or two I was out of the wash and was able to again control the ship. I followed around to make a 360 degree climbing turn to avoid the river, called the tower and made a normal landing. I would like to stress that the violence of the turbulence at that particular moment was so severe that had I waited a few more seconds before applying full power, there is no telling just what would have happened. The

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thing that puzzled me is that the DC-6 was at least 5000 feet in front of me when I crossed the boundary. It seemed that the turbulence just hung at the end of the runway.

Signed: J. Oliver Doern, President
Eagle Brewing Company"

"Washington, D. C.

"I wanted to mention to you that I had somewhat of the same experience returning from a trip from Philadelphia and coming into Washington Airport for a landing was told to follow in closely behind a DC-4, ran into the turbulence at about 100 feet altitude and about 300 yards from the airport. The turbulence practically made me feel I was going to land under the airport instead of on top of it. We finally pulled the ship out about 15 feet above the water and straightened it out and landed. If we had not had an approach speed of about 95 miles per hour, I believe that we would have had somewhat of a serious accident.

Signed: Harrison Somerville"

"Minneapolis, Minnesota

"I had an experience in 1949 which comes squarely within the scope of your inquiry. I was flying a 1947 Stinson Voyager which was based at Wold Chamberlain Airport, Minneapolis, Minnesota. I do not recall the date, but it was during the summer months and just at dusk. Flying conditions were perfect and there was no wind. I was cleared by the tower to land north

NO. 8 - SAFETY SUGGESTIONS

BEECH AIRCRAFT CORPORATION

following a DC-4. On coming over the south border of the airport, the DC-4 had completed its landing run and had turned off the runway and into the ramp on the west side of the field. I was ready to land and still had an altitude of 50 feet, flying speed about 70 mph and was approximately 2000 feet from the point where the DC-4 had turned off the runway when the left wing of my Stinson was pulled violently upward and within an instant the ship was almost upside down and well to the right of the runway. I had the impression that my altitude increased noticeably, but I am not certain.

"With full opposite rudder and full throttle, I got control of the ship within a matter of inches before it hit the ground. By this time I was well to the right or east of the runway and it was necessary to go around and get clearance for another landing.

Signed: I. E. Meagher
Meagher, Geer & Markham"

"Washington, D. C.

"I was returning from New York with two passengers in the Bonanza. The weather was CAVU; the time of day, about 19:30, just before twilight; temperature, approximately 80 degrees F.; wind, calm.

"Received tower instructions for a left-hand traffic pattern to runway 36, Washington National Airport. No aircraft were either in the traffic pattern or, so far as I had observed, had landed or taken

off during my surveillance of the airport which must have been a matter of five to six minutes. Since I had experienced no turbulence whatever during the entire flight, I did not anticipate the sudden "bump" which I received when about 200 feet above the Potomac River and about 1000 feet from the end of the runway. The right wing of the aircraft dropped to about 60 degrees and the plane seemed to fall off sharply in that direction. I had plenty of air speed in which to right the aircraft and continue a normal approach. I did instinctively apply power as soon as the wing dropped but was not too concerned about the incident.

"Curiosity aroused me sufficiently to ask the meteorologist at the weather station in Washington to what he attributed this strange phenomena. As nearly as I can remember he told me that it could have been a miniature whirlwind set up by either a landing or departing aircraft. In the still air this whirlwind had lingered in the vicinity of the airport perhaps even building up some velocity and I had apparently struck the vortex.

Signed: G. C. Whalen, President
American Mercury Insurance Co."

"Oakland, California

"Approximately 4:00 p.m. one afternoon in January of this year, I was approaching Oakland Airport from the north in a Model 35 Bonanza and was told by the tower to make a right hand approach and land short behind a Curtiss C-46 on final as other

NO. 8 - SAFETY SUGGESTIONS

BEECH AIRCRAFT CORPORATION

traffic was following closely. My very first thought was to avoid any turbulence that might be present in the path of this airplane, and, as a matter of fact, I called the tower and told them I could use the gravel area on the north side of the runway but was ordered to land on the runway.

"I spaced myself accordingly and turned on final approach about 1000 feet from the end of the runway at about 400 feet altitude. At this point, the wheels were down, full flaps on, and prop in low pitch with air speed of 80 mph, and airplane trimmed in hands-off attitude. The air was very smooth and stable.

"At approximately 150 feet from the end of the runway, and about 200 feet altitude the plane was thrown violently on its side, left wing down about 70 to 80 degrees, and headed for the ground at terrific speed. During this very brief period, I had no evident control over the airplane. I did have my hand on the throttle and remember applying a considerable amount of power. Recovery was effected about three or four feet off of the ground - far too close for comfort. Witnesses afterward confirmed this saying that they started to run as they saw the Bonanza apparently falling out of control. I still don't know who was most surprised at a recovery that apparently wasn't in the cards.

"I might add that when this occurred, the C-46 was about 4000 feet ahead, had landed, and was turning off of the runway.

Signed: Ivor Witney, Chief Pilot
Pacific Aircraft Sales Company"

"Ventura, California

"First is a total washout of a Cessna 140 in 1950, that was cleared to land by the tower behind a Constellation on a warm day with winds of less than 15 mph, landing to have been made a suitable distance behind the big airplane. Upon crossing the fence at an altitude of about 50 feet the Cessna 140 dropped in a full stall without warning and in a direction at least 45 degrees to the right of the flight path, striking the ground off of the runway. No injuries were sustained by either pilot or passenger; however, damage to plane was beyond economical repair.

Signed: W. W. Hoffman, Owner-Manager
Ventura Airpark"

"Lebanon, Ohio

"In answer to your letter of February 18th on safety suggestions, I thought I would mention that my Bonanza was upset while I was flying into the airport by the slip stream of a DC-6 in July, 1949. On a very still, clear day, I came in on a low, slow approach (about 72 mph) on the end of the runway. The DC-6 was just turning off the other end of the runway. At about 40 feet altitude the turbulence struck, my wing went down and we almost cartwheeled into the ground. The airplane was a complete loss, but we were not hurt at all because our seat belts were tight.

Signed: Corwin S. Fred"

"Cedar Rapids, Iowa

"A letdown in our C-45 was being made into Vandalia Airport at Dayton, Ohio, at night during the fall of the year. A

NO. 8 - SAFETY SUGGESTIONS

Braniff pilot, W. A. Stephens, was flying the ship and the writer was serving as co-pilot. The weather was clear except for a light stratus formation at about 2000 feet which was only about 500 feet thick. After passing through the stratus I used a flashlight to check the leading edge for ice between the engine nacelle and the wing root where my previous experience had led me to believe was the point at which ice was formed first. No icing was observed and the boots were not used. A normal approach was made with good visibility below the stratus and, as I recall it, about a 25 mph surface wind straight down the runway.

"We were cleared to land behind a TWA DC-3 which was taking off and which cleared the far end of the field about the time we crossed the airport boundary at about 50 feet and with a good margin of air speed. Just as Stephens started to flare out, the ship suddenly went out of control due to turbulence obviously induced by the DC-3's take-off. The ship went into a violent snap roll and one wing tip cleared the runway literally by inches. A superb performance by Stephens effected a recovery by instantaneous application of rudder and full power coupled with his demanding instant retraction of gear and flaps. Fortunately he had cleared the carburetor of ice and had advanced the prop controls on the approach so that there was an instant response to the throttles.

"Inspection of the airplane after the go-around revealed that about an inch of rime

BEECH AIRCRAFT CORPORATION

ice had formed on the leading edge near the wing tips and on the leading edges of the tail surfaces. Like most situations when an aircraft gets into difficulty this was a build-up of several factors which combined to result in something really important. In this case it was discovered that while glaze ice may form first on the wing root, rime ice does not necessarily do so, and this coupled with the turbulence created by the DC-3 combined to result in a very close one. Anything you can do to assist pilots to learn these things other than the hard way is certainly a praiseworthy effort.

Signed: Arthur A. Collins, President
Collins Radio Company"

"Bridgeport, Connecticut

"My Navion's approach speed was about 80 IAS - spacing 1/2 to 3/4 miles behind the DC-3 and landing path offset to the windward side of the DC-3 path. Surface wind was slightly cross runway 5-8 mph. At about 75-100 feet above the ground the right wing dropped down so violently that for several seconds, I was in a near vertical bank. This condition persisted for a moment or two even after I had applied full power and some forward movement of the control column.

Signed: Robert D. Smith
LaResista Corset Company"

"Buffalo, New York

"Yes, I have encountered those same conditions as mentioned in your letter. Was flying a BT-13A at the time of accident.

NO. 8 - SAFETY SUGGESTIONS

BEECH AIRCRAFT CORPORATION

Can only say was too close to an American Airline Convair on final approach for landing. With my ship in low pitch and 30 degrees of flap when I hit the wash of other ship ahead. The turbulence put me out of control, down I came 50 feet. One week in hospital.

Signed: William L. Hauck"

"Galesburg, Illinois

"We were about to leave Chicago Municipal Airport, having already completed our mission there, and had taxied out to the prescribed runway. Our stop had been brief and only a short run-up check was required. After completing this, the tower granted take-off permission just as an airline Constellation became airborne. Believe me, it took both of us pilots (Mr. Karrol Bretz, now captain with Wisconsin Central Airlines, and myself) on the controls giving full travel to both right then left aileron, etc., to keep our DC-3 from doing a snap roll just as we became airborne.

Signed: C. L. Crossan, Buyer
Midwest Manufacturing
Corporation"

"Aeschenhof, Switzerland

"I landed with my Cessna shortly after a large DC-4 of Air-France. I intended to roll to the parking place diagonal in the back of the DC-4 and in passing - when suddenly the pilot of the Air-France machine turned on his motors to control the magnetos. My aircraft was blown over

by turbulence and I landed on my head. My airplane was crashed and completely demolished. By great luck, my passenger and I were not injured. I wish to add that I had to fight a lawsuit of three years up to the court of appeal at Paris to receive my indemnification, which was paid to me just a week ago.

Signed: Ernst Muller"

"Bedminster, New Jersey

"We operate several planes here on "air taxi" and have occasion frequently to go into LaGuardia, Idlewild and other air terminals. In several years of this sort of flying, I have had numerous occasions to experience prop wash from airliners on both approach and take-offs.

"Several things can be done by the pilot to minimize danger. Approach steeply and at higher than normal approach speed so that extra control will be available if turbulence is encountered. Stay on the windward side of the runway if there is any cross-wind. On take-off, crab or bank gently to the windward side of the runway which will put you out of any turbulence left from a preceding airliner. Always be ready for turbulence and act rapidly to try to turn out of it or dive the plane to recover control. On one occasion I saw an AT-6 flipped on its back landing behind a B-24 so it isn't only the light planes that can be affected. I believe we can educate tower personnel to this problem and that more effort should be made to

NO. 8 - SAFETY SUGGESTIONS

BEECH AIRCRAFT CORPORATION

direct light planes to short or cross-wind runways at large terminals rather than instruct them to land directly behind four-engine craft.

Signed: Samuel Freeman
Somerset Air Service, Inc."

"The Hague, Netherlands
"KLM reported as follows:

The dangerous influence of turbulence created in the approach area by large aircraft is well known to us. All our pilots are fully aware of this and even large airplanes like Constellations and DC-6's are upset by it. We also wish to draw your attention to the fact that the turbulence in the approach area created by jet aircraft is considerably higher than the turbulence produced by a piston-engined airplane. Pilots of large airplanes have to be seriously on the alert when landing behind jet aircraft.

Signed: D. J. deVries
Hollinda N.V."

"Portland, Maine

"I have seen many light plane pilots run serious risks taking off or landing behind large planes. I have had control towers clear me for take-off behind large planes when it would have been very serious, if not fatal, to fly through the prop wash; and I think that in many ways the prop wash of a large plane on take-off is more dangerous than on landing, because the large plane is operating at full throttle.

"Many control tower operators will clear a light plane into position immediately after clearing a transport for take-off. This is very bad practice. The light plane pilot may get behind the large plane and find that the pilot of the transport runs up his engine before releasing his brakes. I was once a passenger in a Widgeon when we were cleared into position behind an F47. He started to roll and we moved directly behind him. Apparently dissatisfied with the sound of his engine, he stopped and ran it up to full power before releasing his brakes. We were about 75 feet behind him and it was necessary for us to put both our engines almost wide open and to lift our tail in order to prevent being blown backwards into Boston harbor. A very light plane would certainly have been involved in a serious accident under similar circumstances.

"Many years ago I was taught a simple trick which I have since taught to many pilots who should have learned it very early in the game. I take advantage of the fact that airport designers always seem to place runways with a built-in cross-wind. When the wind is slightly off the runway, it is very easy to land or take off on the windward side of the runway and avoid prop wash. But I have ridden with pilots who would do just the opposite, in an attempt to land more directly into the wind, and get themselves into trouble from prop wash.

"Another factor is that the cruising speeds of Bonanzas, Navions and so on, are now

NO. 8 - SAFETY SUGGESTIONS

as fast or faster than the approach speeds of some airliners. The light plane pilot flying a smaller traffic pattern at a speed approaching, and occasionally exceeding, the speed of the transport as he crosses the boundary, sometimes finds himself much closer than he had planned.

"Another thought is that pilots of fighter planes should be very careful to stay away from light planes. The other day an F47 dove on me from behind and pulled up very close in front of me. He scared the day-lights out of me and I instinctively turned, and it is a good thing I did, because although I hit only the edge of his prop wash, it almost rolled the Navion over on its back.

"If private pilots find themselves in traffic patterns with big planes, they must certainly learn extra precautions, and they must learn things their instructors at small fields did not tell them. They must learn that the airliners are slower on final approach than they might think, that the airline pilots have very poor visibility from the cockpit, that they make a very long final approach and that they normally

BEECH AIRCRAFT CORPORATION

carry a lot of power until they have crossed the boundary.

Signed: Roger C. Williams, Publisher
Guy Gannett Publishing Company"

Based on this information, it would indicate that severe turbulence could be encountered behind any large aircraft if the right air conditions prevail.

Recommendations:

1. Allow plenty of space between aircraft in the traffic pattern.
2. Make your approach to and landing on the up-wind side of the runway.
3. Maintain adequate flying speed well above your aircraft's stalling speed, when entering an area just vacated by another airplane.
4. Be alert and prepared for turbulence on your landing approach.

Editor's Note: We wish to thank not only the writers of the letters quoted herein, but also the writers of the over 200 other letters which covered the same subject and which could not be quoted for lack of space. The letters herein were selected for their variety in order to cover the field as thoroughly as possible in a bulletin of this type.

HEADQUARTERS
UNITED STATES CONTINENTAL ARMY COMMAND
Fort Monroe, Virginia

ATDEV-6 452.1/229(7 June 57)

7 June 1957

SUBJECT: Final Report of Test, Project Nr AVN 2656, Effect of
Wing-Tip Vortices and Sonic Shock on Army Aircraft in
Flight

TO: Chief of Research and Development
Department of the Army
Washington 25, DC

1. Inclosed is a copy of Final Report of US Army Aviation Board,
Project Nr AVN 2656, May 1957, subject: "Effect of Wing Tip Vortices
and Sonic Shock on Army Aircraft in Flight."

2. This headquarters concurs in the Board's conclusions and
approves the recommendations contained in paragraphs 5 and 6, respec-
tively, of the abstract of the inclosed report. The recommendations are
as follows:


a. The US Army monitor the study and flight-test program
being initiated by Wright Air Development Center, Air Research and
Development Command, USAF, to study the effect of turbulence on air-
craft landing every 30 seconds.

b. The US Army monitor the sonic boom program being ini-
tiated by Wright Air Development Center, Air Research and Development
Command, USAF.

c. The US Army support further investigation of the sonic
shock and wing-tip vortices problems to the extent necessary to deter-
mine effects on Army aircraft.

FOR THE COMMANDER:

1 Incl
(Over)


SAMUEL J. CHILK
Lt Colonel, AGC
Asst Adjutant General

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ARMY-COMM-0136